Risky decisions: How context modulates our risk preferences

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Introduction

Everyday we are faced with many decisions and choices. These can be simple choices, such as when to get up or what to wear, or more consequential ones, such as whether to buy a house together, or to accept a job abroad. Many of these daily-life decisions include uncertainty about what the outcome will be. More specifically, a risky decision involves a choice between gambles or options in which the probabilities of the outcomes are known, but the outcome is uncertain (Knight, 1921). Choosing whether to undergo a risky operation with a 70% chance of survival, is an example of a risky decision people can face. Often these decisions are influenced by the *context* in which a decision takes place, for instance prior to making the decision we might have experienced good or bad financial outcomes, or the decision to be made could involve others. Choosing on behalf of another person or oneself (which I refer to here as *agency*), for example, or trusting an advisor with one's money, can influence our preference and choice, which we might call a social context. These seemingly relevant contexts are often ignored when studying risky decision-making. The willingness and reluctance to take risk has a major impact across many domains, including health, finance, and politics. Governments spend millions to cut back practices such as smoking, gambling, and taking out high-risk loans. Moreover, it has even been claimed that the current global financial crisis has been instigated by irresponsible risk-taking by people in the higher levels of financial institutions. It is thus of high importance to better understand why individuals display this risk-seeking behaviour, and how different contexts can influence risk decisions.

The aim of this thesis is to study how different social and non-social contexts influence our preferences and choices concerning risk. More specifically, I will investigate how different types of contexts, unrelated to the choice outcome itself, can influence decision-making behaviour. I will address this by examining human behaviour, and also how the brain evaluates contextual information prior to a risky choice.

Decision-making under risk

It has been well established that people dislike choice options with outcomes that are uncertain or risky. That is, they shy away from options with increased risk, even when the expected value one receives from choosing an option is equal or higher than the non-chosen option (Tversky & Kahneman, 1981, 1992). For instance, given a choice between a certain €20, or a gamble to win €45 determined by a coin flip, i.e. heads you win €45, tails you win nothing, people overwhelmingly prefer the certain €20. This aversion to risk when the risky option offers higher value is inconsistent with classical models of decision-making under risk. These models have been of major influence to the study of risk-taking.

Models of risky decision-making

According to classical economic models of decision-making under risk (e.g. normative decision theory), “good” decision-making involves choosing the option that maximises one’s expected value, assuming full information is available and one has the capacity and motivation to make the choice. Expected value is a quantity obtained by multiplying the “payoff” or magnitude of the outcome with the probability of this outcome occurring (Baron, 2007). This theory states that choice preferences should be independent of the context in which a decision is presented, and should be transitive, i.e. people should always choose the option that yields the highest objective value. Although this model sounds reasonable, in reality people do not consistently choose the option with the highest expected value (Platt & Huettel, 2008). For example, many choices contain different commodities (e.g. buying a new computer vs. choosing where to go out to) that are difficult to compare (Kahneman & Tversky, 1979; Baron, 2007).

Moreover, Bernoulli (1738) proposed the concept of marginal utility, which means any increase in wealth (quantity of goods), will result in an increase in utility that is inversely proportional to the quantity of goods already possessed, and thus, wealth is not simply its monetary value. In other words, the subjective value of a gain or a loss is determined from a particular starting point or current state, i.e. reference dependent. Additionally, this value marginally diminishes. For instance, an increase of €100 provides more utility (i.e. looms larger) to a poor person than it does to a wealthy person.

To overcome this problem, Expected Utility (EU) Theory emerged (Von Neumann & Morgenstern, 1944). This theory introduced utility as a common currency to compare choices. It can be seen as a subjective value of goods whereby people should choose the options that maximise their *expected utility* (Von Neumann & Morgenstern, 1944). Defining the highest expected ultility typically involves the probability multiplied by the subjective utility, based on Bernoulli’s marginal utility.

Thus, the aversion to risk in the above example can be explained by the findings that the additional value of the gamble does not provide much more subjective value to overcome the reluctance to take a risky choice.

Context-dependent risky decision-making

An intriguing observation is that peoples’ preferences to avoid or take risk are quite unstable, and that the context of the decision can influence peoples’ risk preferences. That is, while people are generally risk-averse, after experiencing losses they typically become markedly risk-seeking. These shifts in risk preferences have been observed in many daily scenarios, such as in trading (Brown Harlow & Startls, 1996), betting at racetracks (Hausch, Ziemba & Rubinstein, 1981), health decisions (Levin Gaeth, Schreiber & Lauriola, 2002), as well as with populations such as pathological gamblers (Campbell-Meiklejohn Woolrich, Passingham & Rogers, 2008). In fact, studies have demonstrated peoples' willingness to shift their risk preferences depending on prior gain and loss outcomes (*contexts*), even when these outcomes are independent of the choice outcome (Barkan & Busemeyer, 1999, 2003; Xue, Lu, Levin & Bechara, 2011; Hytönen et al., 2014).

Decades of behavioural work in psychology (e.g. Kahneman & Tversky, 1979) have convincingly demonstrated that outcomes unrelated to the decision at hand (e.g. financial gains or losses) play an important role in determining our choices. One of their influential examples shows how decisions framed as gains or losses influence choice. For instance, participants were asked to choose between two treatment programmes to combat a hypothetical Asian flu that was expected to kill 600 people. They proposed this problem in either a positive or a negative context (frame). Programme A would save 200 lives for certain, whereas with programme B, 600 lives would be saved with a one-third chance. The other group was told that they could either choose programme C, whereby 400 people would die for certain, or programme D whereby there would be a two-thirds chance that all 600 people would die. Interestingly, these subjects showed a preference reversal when the frame changed, even though the expected value of these four options is equal. Here, people showed an aversion to risk in the positive framed problem and preferred programme A with a certain gain of 200 lives. In the negative framed problem, in contrast, people were more risk-seeking and preferred programme D, taking the risk (i.e. two-third) that everybody would die (at the same time taking a chance of one-third to save everyone). This phenomenon, known as the framing effect, was one of the findings that led to an alternative descriptive theory to the expected utility theory, called Prospect Theory. To this day, this is still one of the most successful behavioural models of decision-making under risk and uncertainty.

Prospect Theory

Prospect theory (Kahneman & Tversky, 1979) proposes that people tend to evaluate the outcomes of a decision to a change from a flexible reference point. Therefore, gain and loss outcomes are evaluated relative to this reference point rather than in absolute terms. Moreover, in line with Bernoulli's marginal utility (1738), independent of the current state, the impact of a change in value diminishes marginally with the distance from a relevant reference point. Additionally, it has been theorized that people weigh losses more heavily relative to gains of similar value. For instance, people typically reject gambles that offer a 50/50 probability of gaining or losing money, unless the amount that could be gained is about twice the amount that could be lost (e.g. a 50/50 probability to either gain €100 or lose €50) (Tversky & Kahneman, 1981). This phenomenon is illustrated by a steeper slope for losses than gains in the value function, and is referred to as the concept of *loss aversion*. The disproportionate evaluation of losses and gains makes people more sensitive to losses of money or objects (Kahneman & Tversky, 1979; Tversky & Kahneman, 1981, 1986), and highly motivated to avoid them. This explains why people become risk-seeking in case of a choice concerning losses.

The main interest of this thesis is to understand how risk preferences are altered by different positive and negative contexts, contexts that are objectively independent of the risky choices themselves. Additional insight can be gained by examining how the brain evaluates different contexts and how these neural responses may predict subsequent risky decision-making. Examining both behaviour and brain processes would be beneficial for our understanding of risk preferences more generally.

Neural correlates of decisions under risk

The neural mechanisms underlying risky decision-making depends on the anticipated subjective value (utility) one receives from probable reward and punishment outcomes. The brain processes inputs from multiple brain regions, and integrates and compares these to a final value signal that reflects a preference for one of the available outcomes.

Brain areas associated with the evaluation of gains/losses and with value-guided decision-making are, among others, the ventromedial prefrontal cortex (vmPFC), striatum, and insula (Breiter, Aharon, Kahneman, Dale & Shizgal, 2001; Delgado Locke, Stenger & Fiez, 2003; Tom, Fox, Trepel & Poldrack, 2007; Rangel & Hare, 2010; Basten, Biele, Heekeren & Fiebach, 2012; Boorman, Rushworth & Behrens, 2013). These structures have also been important for risk (Bechara, Damasio, Damasio & Anderson 1994; Critchley, Mathias & Dolan, 2001; Campbell-Meiklejohn et al., 2008; Sanfey, Hastie, Colvin & Grafman, 2003; Shiv, Loewenstein, Bechara, Damasio & Damasio, 2005). In particular, the nucleus accumbens (NAcc), a part of the striatum, exhibited increased activity when anticipating risky gains, whereas insula activity increased when anticipating risky losses (Kuhnen & Knutson, 2005; Knutson & Geer, 2008). The anterior insula (AI) has also been found in relation to the expectation of losses (O'Doherty, Dayan, Friston, Critchley & Dolan, 2003; Paulus & Stein, 2006) and risk-taking concerning gambles to win or lose double-or-nothing, both for using nonmonetary incentives (Paulus, Rogalsky, Simmons, Feinstein & Stein, 2003), and monetary rewards (Critchley et al., 2001).

Some studies have explored the neural correlates of gain and loss contexts in risk-taking. Tom and colleagues (2007) observed that when people are confronted with a decision involving both potential gains and potential losses (i.e. mixed gain-loss gamble), risk-taking recruited the neural substrate involved in the approach of rewards, while risk-avoidance was correlated with the neural substrate involved in loss aversion. They suggested that the disutility to anticipated losses kept people from accepting the gamble. However, other studies showed that both the disutility to losses and an increased emotional response correlated to the decision to avoid a potential loss outcome (Canessa, Motterlini, Alemanno, Perani & Cappa, 2013; De Martino, Camerer & Adolphs, 2010). Additionally, De Martino and colleagues (2006) demonstrated the susceptibility of risk preferences to different gain or loss framed choices, which induced a framing effect. They reported that subjects who were sensitive to the gain/loss context frame exhibited enhanced amygdala activity, indicating that the resulting behavioural framing effect was biased by emotional processes.

As described, there are many contextual forces that can have a large impact on our risk preferences. People are often not fully aware of their preferences, and therefore can be susceptible to influences that are in fact irrelevant to the choice at hand. These studies indicate that brain areas involved in anticipating and processing reward and punishment outcomes are critically involved in risk-taking decisions. However, empirical evidence remains limited about how different, unrelated, positive and negative contexts might influence risk preferences for identical sets of risky choices. This is an interesting question, since many real-life decisions in which we choose between a more or less risky outcome often takes place in different contexts which can be objectively unrelated and uninformative to the choice.

Decision-making under risk in social contexts

So far, I have discussed how reward and punishment contexts affect risk preferences on an individual level. Risky decisions can also take place in social contexts that are slightly different from standard reward and punishment contexts, such as a situation in which the role of agency changes (first- or third-person decision); for instance, deciding for a friend (Beisswanger, Stone, Hupp & Allgaier, 2003) or when representing a group (Reynolds, Joseph & Sherwood, 2009), but also decisions taking place in a social environment (deciding whether to trust another person with one's money). Despite the apparent ubiquity of situations in which social contexts may influence individual preferences for risky and uncertain outcomes, there is a surprising dearth of research examining choices made for another person for both social and non-social decisions. One of the open questions here is how positive and negative contexts may impact our preferences for risk and decisions when the outcome does not involve us directly, but the other person for whom we decide. Additionnally, how changing agency alters our social preferences in social risky choice settings.

Agency

A great deal of research on decision-making for others has been conducted in the context of medical decision-making, or surrogate decision-making. For example, the decision whether one's parent should be taken into a care home, or whether one should undergo a risky operation, are decisions often delegated to another person. In this thesis I am interested in how risky decisions are actually taken when agency changes, that is, choosing on one's own behalf (so-called *first-person*) and on behalf of another person (so-called *third-party*). Often these decisions involve outcomes that are uncertain or risky, due to the fact that the outcome of these decisions are also dependent on other peoples' decision behaviour. Moreover, an additional undertainty that may arise when choosing for an anonymous person is not knowing their preferences.

Currently, the literature on decision-making for others has not given a consistent view of how deciding for a third-party affects risk preferences. Risk-taking concerning monetary outcomes (Agranov & Bisin, 2011; Chakravarty, Harrison & Haruvy, 2011; Pollmann, Potters, Trautmann, 2014; Hsee & Weber, 1997), or outcomes affecting others (Beisswanger et al., 2003; Wray & Stone, 2005) increased when choosing on behalf of a third-party. However, increased risk aversion on behalf of a third-party has also been observed for monetary (Eriksen & Kvaloy, 2010; Reynolds et al., 2009), medical (Garcia-Retamaro & Galesic, 2012) and social choices, although this was only observed in one-third of participants (Charness & Jackson, 2009). Furthermore, studies also demonstrated that when deciding for another person, loss aversion was attenuated (Polman, 2012). Additionally, some studies have not observed any difference between third-party decisions and decisions made by oneself (Stone, Yates & Caruthers, 2002). One reason for the inconsistent findings reported in the literature could be a result of examining different phases of the decision, as well as different types of decisions. For example, studies have looked at decisions concerning advising anonymous others or friends (Beisswanger et al., 2003; Lu, Xie & Xu, 2013), predicting others' preferences (Hsee & Weber, 1997), and making actual choices on behalf of others (Civai, Corradi-Dell'Acqua, Gamer & Rumiati, 2010; Chakravarty, Harrison, Haruvy & Rutström, 2011; Jung, Sul & Kim, 2013), either tested within- or between-subjects, and for different choice outcomes, (e.g. concerning social or non-social outcomes, that were either hypothetical or real). Therefore, it remains unclear how social and non-social contexts influence preferences for risk-taking.

One important process that may play a role in agency and risk is the extent of involvement of the decision-maker. Individuals who actively choose an option are also responsible for the outcome of their choice. Studies have shown that enhancing responsibility or even accountability can influence peoples' preferences for risk in the direction that reduces the direct agency of the decision-maker (Charness & Jackson, 2009; Eriksen & Kvaløy, 2010; Reynolds et al., 2009; Vieider, 2009; Pollmann et al., 2014).

Taken together, the literature on third-party decision-making demonstrates that choice preferences can alter when varying personal involvement, compared to when choosing for oneself. An interesting and important question to study is whether personal involvement in the decision and outcome alters the impact of reward and punishment contexts, and how this affects subsequent risky choices described earlier.

Agency in social environments

Many decisions take place in social environments or contexts, that is, when others are also involved in the outcome. A type of decision that involves and affects others is cooperation. The decision whether to collaborate in recycling garbage for the benefit of the environment is a typical example of cooperative behaviour for a good shared by the public (i.e. public good). Cooperation is often perceived as a social dilemma, because one does not need to cooperate to still enjoy the public good. This characteristic provides the incentive to "free-ride", and let others put in all the effort and costs. Given this knowledge, cooperation is then perceived as a prosocial behaviour that requires a person to make a trade-off between self-regarding preferences and other-regarding preferences, with a risk of potential free-riding.

Intriguingly, important cooperative decisions for a public good are often made by a representative of a group. An open question is whether decisions on behalf of others are made differently when placed in a cooperative context. Specifically, does personal involvement in the outcome of the public good influence this, or does personal involvement not matter? The previously described literature on risk and third-party decisions seems to suggest that third-party preferences differ from individual preferences. To know whether personal involvement affects cooperative and third-party decisions will help establish which psychological process is essential for cooperation, and third-party preferences.

Classical economic Game Theory – which mathematically models and aims to understand strategic behaviour in social interactive settings (Von Neumann & Morgenstern, 1944) assumes that people should always choose the option that maximizes self-interest, specifically if all others also act out of self-interest. Work in psychology has demonstrated that economic models do not always correctly predict individuals' behaviour in social settings. It has been shown that people do not act out of pure self-interest, but also value others' interest, demonstrated by cooperation (Fehr & Gächter, 2000; Fischbacher, Gächter S & Fehr, 2001), and in bargaining decisions (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003; Rilling & Sanfey, 2011).

Cooperative decisions can be observed as socially uncertain decisions (Trautmann & Vieider, 2011), for example, not knowing what the other agents' intentions are, and whether they will cooperate or defect (i.e. not cooperate). As described earlier, people are generally risk averse, and this could motivate individuals to not cooperate, but to choose the safest option for their own benefit (i.e. free-ride), despite that this may harm the collective in the long run. Psychological factors such as the ability to mentalize or view the decision from the other persons' perspective (McCabe, Houser, Ryan, Smith & Trouard, 2001) have shown to influence the willingness to cooperate when deciding for the self. Moreover, theory-of-mind processes have shown to modulate other-regarding preferences (Janowski, Camerer & Rangel, 2012), which are associated with perspective-taking or mentalizing about others intentions, thoughts and beliefs (Amodio & Frith, 2006; Frith & Frith, 2006). Furthermore, other factors such as a desire to behave in line with social norms (Fehr & Fischbacher, 2004a) have shown to influence social choices. Most of these motivations influencing cooperation are inherently social. In situations where these decisions are delegated to others, it is unclear if and how these motives play a role. For instance, varying personal involvement might influence the ability to take the perspective of others, influencing the decision to cooperate.

A few studies that have examined third-party decisions in social contexts highlight potential differences and similarities in preferences relative to decisions made for the first-person, providing some helpful insights into how they may influence decisions in cooperation. One study showed that third-party decisions have higher preferences for risk averse choices in settings they were jointly involved in, such as deciding for both a partner and themselves in a stag-hunt game (Charness & Jackson, 2009). Fairness decisions did not show rejection rates for a third-party to differ from rejection rates for oneself (Civai et al., 2010). Interestingly, though not demonstrating a behavioural difference, the negative emotional response observed when receiving an unfair offer for oneself, was decreased when receiving an unfair offer on behalf of a third-party (Civai et al., 2010). This suggests that the decision-maker's role does have some impact.

In sum, these studies suggest that choice preferences when choosing for a third-party can differ compared to choices made for oneself, both behaviourally as well as in underlying processes. Specifically, the extent of the decision maker's personal involvement suggests that this plays an important role in preferences for risk and also preferences concerning outcomes related to other people. A possible role of perspective-taking in decisions involving others and third-party decisions may influence preferences in line with other-regarding preferences. In this thesis, I aim to explore how personal involvement affects our social preferences in risky settings.

Approach to study risky decision-making

In this thesis I aim to explore the basic processes of context-dependent risky decision-making for both self and third-party decisions, by adopting a neuroeconomic approach. This approach lies at the intersection of fields such as economics, psychology and neuroscience. I will briefly describe the how each discipline contributes to the science of decision-making.

The aim of *Economics* is to specify simple models of human real-life choice behaviour in ways that predict optimal decisions. The purpose of these *normative* economic models is to describe choice behaviour of rational agents. The strength of this field stems from its many simple usable models and paradigms to examine decision behaviour in individual and social choice problems. In reality, however, people do not consistently choose the economic rational option (i.e. highest expected value or utility; Platt & Huettel, 2008), which has led to the formation of new theories from Psychology.

Neuroscience aims to understand how people make decisions and in particular, how the different decision variables are computed, compared, and integrated at the neural level. The strength of this field is that it enables real-time measurement of neural processes underlying decision behaviour, and can thereby, in combination with behavioural data examine more accurately how people make decisions. For example, in situations where the same behavioural output can be explained by two different processes that correlate to distinct neural processes, neuroscience can provide insights and generate new hypotheses regarding existing theories. Functional magnetic resonance imaging (*f*MRI) is one of the brain imaging techniques used in this discipline, and in this thesis (see Box 1). An issue in neuroscience is the labelling of a cognitive process to specific activated brain regions (i.e. reverse inference; Poldrack, 2006). Cautious interpretations of brain data are therefore required, and by integrating other measures (i.e. behaviour, scales, existing theories about processes that have been associated with specific areas in a structure), neuroscience can provide substantial scientific insight.

Psychology aims to understand choice behaviour by observing how humans make decisions, taking into account human motivations and limitations. This discipline has built up an extensive dictionary of psychological factors that influences human behaviour and proposes many theories about behaviour (e.g. Prospect Theory). Their paradigms often contain high ecological validity. A limitation to this field is that many theories are based on simple self-report questionnaire measures or single choice or hypothetically based studies, which are often confounded by the human capacity to consciously report their behaviour and intentions. Besides these limitations, research in psychology has made major advances to the study of decision-making. Importantly, they have demonstrated that many decisions deviate from the classical economic models. They showed that people do not consistently choose the economic rational option (Platt & Huettel, 2008). This led to the formation of new *descriptive* models of decision-making (e.g. Prospect Theory; Kahneman & Tversky, 1979). These models describe *how* people actually make decisions. They show that when choosing between different options people are not purely guided by the highest economic return, but also strongly guided by underlying emotions and other psychological factors, such as their sensitivity to losses, or responsibility for the outcome.

In the 1990s, these disciplines were combined into a new discipline called *Neuroeconomics*. This discipline integrates theories from each discipline described above. Using the strengths and tools of each individual discipline, neuroeconomics aims to gain a richer understanding of decision-making (for a detailed overview, see Glimcher, Camerer, Fehr & Poldrack, 2009). A variety of methods are combined to studying decision-making, such as *f*MRI (see Box 1). Neuroeconomics has the potential to advance our knowledge of existing theoretical accounts by constraining models based on the underlying neurobiology, and can also be used to inform public policy debates.

Box 1 *functional* Magnetic Resonance Imaging (*f*MRI)

*f*MRI is a non-invasive method that indirectly measures neural activity while the participant is performing a cognitive task. *f*MRI measures regional changes in the level of blood oxygenation, captured as a blood-oxygenated-level-dependent (BOLD) signal (Huettel, Song & McCarthy, 2008). Energy, in the form of oxygen, is bound to haemoglobin in red blood cells (oxygenated haemoglobin). Brain areas that exhibit more activity (e.g. while performing a cognitive task) have an increase in oxygen uptake, which results in increased levels of de-oxygenated haemoglobin in the blood and triggers the body to increase blood flow to that particular brain region (Buxton, Wong, & Frank, 1998). The BOLD response is noisy due to the physiological properties and technical constraints, and therefore, multiple trials as repeated events are used and averaged to gain a single and less noisy signal (Huettel et al., 2008).

Aims and outline of the thesis

The main aim of this thesis is to explore and gain more insight into the psychological and neural mechanisms underlying risky decision-making, both in social and non-social contexts. Previous literature uncovered important aspects of individual and social decision-making, particularly focusing on how these choices impact the decision-maker. Often, the context in which the decisions are made has been ignored when studying decisions. This thesis investigates both these aspects of decision-making, with the focus on how reward and loss contexts, and personal involvement can impact risk and social preferences. I examine how decisions for the individual and decisions on behalf of third-parties may alter fundamental risk processing, in social and non-social contexts. In order to address these issues, behavioural paradigms in combination with fMRI were used. The aims of this thesis were explored in 4 empirical chapters (Chapter 2 - 5).

The main question of the first two chapters is both how and what type of reward and punishment contexts affects peoples' preferences for monetary risk. **Chapter 2** examines *how* gain and loss contexts based on performance at an unrelated task affect subsequent risk choices for monetary gambles. Specifically, it explores the neural processes during the evaluation of moment-by-moment changes of gain and loss contexts prior to a risky decision situation. The aim is to gain greater insight into the mechanisms underlying risk valuation and preference, and demonstrating how these responses can predict and influence subsequent preference for either risky or safe choice options. To follow up on this, **chapter 3** explores how different *types* of gain/loss contexts affect risk preferences. Often these prior gain and loss contexts are also related to the outcome of players' actions, i.e. performance (chapter 2). Specifically, in this chapter, we aim to test whether contextual effects on risk are purely driven by the receipt of random monetary gains and losses (e.g. from a lottery), or whether risk preferences are affected by non-monetary contexts, such as success or failure in performance at a task. To address this aim, different types of rewards and punishments prior to identical sets of monetary gambles are directly compared. This chapter provides a better understanding how risk preferences may be altered by different, unrelated, contexts, and specifically gains a better idea whether these are primarily driven by the aversion to losses, or other factors (e.g. valence of positive/negative contexts)

The main question of the following two chapters is how social preferences – when deciding for a third-party – may alter risk preferences for reward and loss contexts. Moreover, it examines how social preferences may alter decisions in social interactive contexts (e.g. cooperation). **Chapter 4** specifically investigates the influence of monetary reward and punishment contexts on risk preferences for a social other (using a similar design as chapter 2 and 3), and additionally investigates how varying degrees of responsibility can impact these preferences. Understanding how people make risk decisions on behalf of a third-party is a question of substantial interest for society and more generally for the understanding how risk preferences are influenced. **Chapter 5** examines whether cooperative decisions (i.e. a form of social risk) might differ when decisions are delegated to others (i.e. a third-party). The first aim is to gain a better understanding of how cooperative decisions may change as a function of whether the decision-maker is personally involved in the outcome or not. Also, we are interested in which direction these differences lie. Are third-party decisions more pro-social or more pro-self? Comparing third-party cooperative decisions with cooperative decisions on behalf of the self, allows for examining the importance of personal and economic involvement in the public good. The second aim is to specify which motives are important for third-party decision-making, and how these might impact the social preference of cooperation. To answer this, I examine how peoples' willingness to cooperate on behalf of a third-party alters when playing in different social and non-social contexts, thereby varying the conflict between social motives and self-interested motives.

Finally, a summary of the main findings, contributions, and challenges to studying risky decision-making, and more broadly the existing field of neuroeconomics, are discussed in **Chapter 6**.

2

Neural mechanisms underlying context-dependent shifts in risk preferences

Abstract

Studies of risky decision-making have demonstrated that humans typically prefer risky options after incurring a financial loss, while generally preferring safer options after a monetary gain. Here, we examined the neural processes underlying these inconsistent risk preferences by investigating the evaluation of gains and losses, and demonstrating how these responses can impact subsequent preference for either risky or safe choice options. Participants performed a task while undergoing fMRI in which they experienced both gains and losses. Immediately following a gain or loss, participants decided to either play or pass on a "double-or-quits" gamble. The outcome of the gamble could either double or eliminate their initial gain (from the time-estimation task) or redeem or double their initial loss. If they chose not to play this gamble, they retained the initial gain or loss. We demonstrate a shift in risk-taking preferences for identical sets of gambles as a function of previous gains or losses, with participants showing a greater preference towards riskier decisions in the context of a prior loss. An interaction between evaluating gain/loss contexts and subsequent behavioural risk pattern revealed an increased BOLD response in the ventromedial prefrontal cortex (vmPFC), with stronger responses for both gambling in a loss context and safety in a gain context. This suggests that the vmPFC is responsible for integrating these contextual effects, with these processes impacting on subsequent risky choice.

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Introduction

In daily life, people are typically faced with numerous risky decisions, for instance choosing whether or not to buy insurance on an expensive smartphone, or whether to invest money in stocks or save it for retirement. When deciding what to choose in a risky, uncertain environment, people generally exhibit risk averse tendencies, that is, they generally shy away from options with increased risk, even when the so-called expected value of the choice options are equal (Tversky & Kahneman, 1981, 1992). That is, if given a choice between €10 for sure and a gamble with a 50% chance of €20 and a 50% chance of €0, people overwhelmingly favour the certain €10, and in fact the 'winning' outcome of the gamble usually needs to be considerably higher to induce players to choose the risky option. Classical models of economic decision-making (e.g. utility theory and its variants) also assume that these individual choice preferences should be consistent over situations in which the same choice set is offered. For example, the decision to purchase a €5 lottery ticket should not be affected if you had previously either just found €5 on the street, or if alternately you had unfortunately just lost €5 from your wallet – the choice to spend the money to buy the lottery ticket should in theory be independent of these two events. However, several decades of behavioural work (e.g. Kahneman & Tversky, 1979) have convincingly demonstrated that outcomes unrelated to the decision at hand (e.g. recent financial gains or losses) do in fact play an important role in determining our choices. For example, Xue and colleagues (2011) had participants play a task where they decided to play or pass on a gamble consisting of one cup with a large gain and multiple cups with small losses, varying in expected value. They showed that participants decided to play the gamble more often after they lost the gamble on the previous trial, whereas when they won the gamble on the previous trial they were more reluctant to play the gamble.

In fact, when deciding between relatively risky and a relatively safe options, individuals typically have higher preferences for riskier options when the choice is made immediately after experiencing a financial loss (which we term here a *loss context*), while they generally prefer safer options when the choice takes place after experiencing a financial gain (i.e. *gain context*) (Tversky & Kahneman, 1992). This phenomenon can occur even when faced with a choice set presented as either gains or losses (Tversky & Kahneman, 1981; De Martino et al., 2006; Porcelli & Delgado, 2009).

In the current study, we are interested in exploring the neural processes underlying these inconsistent risk preferences following gains and losses respectively. Specifically, we aim to gain greater insight into the mechanisms underlying risk assessment and preference, by investigating the neural substrate during the evaluation of gains and losses prior to a risky decision situation and demonstrating how these responses can predict and influence subsequent preference for either risky or safe choice options.

Vitally important for decision-making is an adequate evaluation of gains and losses, as these outcomes usefully inform us whether or not to continue a particular behavioural strategy (Barto & Sutton, 1997). Brain areas associated with the evaluation of gains/losses and with value-guided decision-making are, among others, ventromedial prefrontal cortex (vmPFC), striatum, and insula (Breiter et al., 2001; Delgado et al., 2003; Tom, Fox, Trepel & Poldrack, 2007; Rangel & Hare, 2010; Basten et al., 2012; Boorman et al., 2013). For instance, Tom and colleagues (2007) observed that when participants were presented with a mixed gamble offering an equal chance of a monetary gain or loss, BOLD responses in striatum and mPFC increased with the size of the monetary gain; in contrast, BOLD responses in the insula increased with gambles containing greater losses. Similar effects were found when gain and loss outcomes were anticipated (Breiter et al., 2001; Knutson et al., 2001; Kuhnen & Knutson, 2005), or when the gain and loss were not monetary but instead delivered in the form of primary incentives, such as tasty versus nontasty liquids (see also Bartra, McGuire, & Kable, 2013). Different decision parameters (e.g. outcome evaluation, choice riskiness, magnitude) are believed to be integrated via a common network in the assessment of choice preference and guiding subsequent behaviour. Interestingly, this network, in particular the vmPFC may play an important role in integrating the gain/loss outcomes and in light of choice options to assess their subsequent preference.

Moreover, studies have shown that the vmPFC is also involved in the prediction of choice. Studies found that while viewing different goods the vmPFC response correlated with the actual preference for those goods, even in the absence of choice, suggesting that the vmPFC also reflects a choice preference signal prior to making a choice (Lebreton, Jorge, Michel, Thirion & Pessiglione, 2009; Levy, Lazzaro, Rutledge & Glimcher, 2011). Specifically with regard to value-based decision-making, the medial orbitofrontal cortex (mOFC) and vmPFC, including striatum and insula, exhibit a significant increase in signal for options yielding higher expected value, and a significantly reduced signal for options yielding lower or negative expected value (e.g. loss) (Platt & Huettel, 2008; Rangel, Camerer & Montague, 2008; Rangel & Hare, 2010; Tom et al., 2007). Options that have ultimately been chosen, with respect to those that have not been chosen, also correlate with the value response of the vmPFC (Boorman et al., 2009).

In particular, the vmPFC has been suggested as a general "hub" for value-guided decisions. This area has strong connections with other reward- and control-related areas (Grabenhorst & Rolls, 2011). It has been suggested that vmPFC guides the valuation process (Plassmann, O'Doherty & Rangel, 2010; Rangel et al., 2008), taking into account the decision-makers goals and the current context, by integrating information signals related to the valuation of rewarding and aversive outcomes, choice signals, and signals from regions involved in cognitive control (e.g. IFG, lateral PFC; Hare, Camerer & Rangel, 2009; Weller, Levin, Shiv & Bechara, 2007; Rosenbloom, Schmahmann & Price, 2012). The aforementioned studies imply the vmPFC may be a key region that operates in shaping preference for which choice option to pursue. However, a relevant question is how different values related to each phase of the decision are integrated and updated, and subsequently impact the decision process. More specifically, it is important to understand how appraisals of the context (i.e. gain and loss) of choice guide subsequent decision-making.

We hypothesize here that in the light of different gain and loss contexts prior to making a risky choice, engagement of the vmPFC may mediate risk preferences in line with the behaviour described by previous studies, that is, a stronger involvement for risk avoidance in the gain context and for risk seeking in the loss context.

To investigate this, in the present study we varied the delivery of monetary gains and losses preceding a risky choice. We expected that this contextual change would in turn alter risk preferences, even though the actual choice facing the participant was the same in each event. We expected that the engagement of the vmPFC reflected a combined value of the appraisal of the current gain or loss by the subsequent anticipated choice and outcome, and that this relative engagement would be potentially predictive of the degree of riskiness of subsequent decisions in the context of gains or losses.

Materials and Methods

Participants

Thirty undergraduate students participated in the study. All provided written informed consent and were financially compensated via a flat fee (25 Euro) for completion of the task. In addition, they also had the opportunity to win a bonus on top of this participation fee, a maximum amount of 10 Euro. Exclusion criteria were self-reported claustrophobia, neurological or cardiovascular diseases, psychiatric disorders, regular use of marijuana, use of psychotropic drugs, or metal parts in the body. Four participants were excluded due to technical problems during scanning. Data is therefore reported from twenty-six participants (14 men and 12 women, M = 22 years, SD = 2.68, range = 19 to 27 years, all right-handed). The study was approved by the local ethics committee.

Task design and procedure

We developed a novel paradigm in order to study risk-taking behaviour in the context of prior gains and losses. Each trial began with a simple time-estimation task in which participants either won or lost money depending on their performance (Boksem, Kostermans & De Cremer, 2011). The purpose of this task was to induce either a gain or a loss context. Directly after the gain or loss feedback from the time-estimation task, participants received a mixed (50/50 chance, gain/loss) gamble (see Figure 1), which they could decide to either pass or play. If they decided to pass on the gamble they would simply retain their gain or loss from the preceding time-estimation trial, which would then be added to the total balance of the money won so far. However, if they decided to play the gamble, the gamble was resolved for them and the corresponding win or loss amount was added to their total experimental balance. The mixed gamble contained either a positive expected value ('+ EV'), a negative expected value ('- EV'), or an equal expected value ('0 EV') by varying the gain or loss outcome from €1.00, €1.20, to €1.40 as compared to the 'pass' option (i.e. choosing to keep the €1.20 gain or loss) (Table 1). We created these three different gamble types to assess whether participants were attending and sensitive to the expected value of the gamble.

Table 1 Mixed gambles by expected value (EV) and EV type .[a]

50|50 mixed gamble	Expected value (EV)	Gamble type
- €1.40 | + €1.20	-0.10	- EV
- €1.20 | + €1.00	-0.10	- EV
- €1.20 | + €1.20	0	0 EV
- €1.00 | + €1.20	0.10	+ EV
- €1.20 | + €1.40	0.10	+ EV

[a] All gambles contained of a 50-50 probability to lose-win money

This study differs in important ways from previous efforts to assess contextual influences on risky decision-making (such as the 'framing effect'; Kahneman & Tversky, 1979; Tversky & Kahneman, 1981; De Martino et al., 2006). The current task design allowed us to disentangle the context from the decision itself. In other words, the current task design enables us to test how a gain/loss context influences risk preferences for identical choice sets. Other tasks (Porcelli & Delgado et al., 2009) have not been able to purely disentangle the choice from the context, as the gambles were not of comparable value, but contained either only losses or only gains. Other studies (De Martino et al., 2006) have manipulated the decision options by phrasing them either as a gain or a loss, even though the outcome of the options always had a positive expected value (i.e. contained an expected gain). To avoid this confound, we implemented a task design where we can always compare the decision play or pass on a gamble using the same gambles across both gain and loss contexts. Other studies (Xue, Lu, Levin & Bechara, 2010, 2011) have used mixed gambles too, however not by separating them from the respective context, as these studies only looked at previous outcomes of these gambles on subsequent behaviour for other mixed gambles. As shown by these studies, the presentation of a choice can substantially affect how people perceive risk, and subsequently how much risk they decide to take. The current design therefore provided a more precise measure of the effect of gain/loss context on subsequent risky decision-making. The gain/loss context in our design is unrelated, in the sense that it is an outcome related to a different, independent, task.

Procedure

Participants first performed two practice sessions of 5 minutes each while lying in the MRI scanner. In the first session participants practiced the time-estimation trial. Here, participants were required to estimate a one-second time duration. After a cue on the screen changed colour, they were instructed to wait exactly one second and then press a response button, with their precise response times recorded. We used the minimum and maximum response times to determine an initial allowable response time-window in the experiment, which in turn was used to give feedback on whether the time-estimation was correct or incorrect.
The second session gave participants the opportunity to practice the gambling task. This session was run concurrently with the collection of an anatomical scan. After these practice sessions, the experiment lasted for one continuous run of approximately 60 minutes, while collecting fMRI data.

Before beginning the task, participants were instructed that their goal was to win as much money as they could, and that their final balance would be paid out as a bonus (with a maximum amount of €10) in addition to their participation fee (a flat fee of €25) for completion of the task. Hence, participants total payment at the end of the experiment would range between a minimum of €25 and a maximum of €35. At the start of each trial, participants saw a red visual cue that changed in colour to white after 1200 ms (Figure 1). Participants were then required to press the response button exactly one second after this colour change. Responses to this time-estimation task were considered correct when they were within an allowable time-interval. For correct responses, participants gained €1.20. Participants lost €1.20 if their response was not within this time-interval, i.e. either too fast or too slow.

The allowable response-interval was initially calculated based on their performance in the practice run and then covertly adjusted throughout the task as a function of the variance in response time of the participant, in order to ensure an equal number of gains and losses on this task. Therefore, if participants responded within the allowable response-interval, this interval was shortened by 5 ms; if they responded either too quickly or too slowly, the interval was lengthened by 5 ms. Importantly, although the number of gains and losses was manipulated, the feedback was contingent upon participants' performance. What differed between participants was the time-interval within which responses were considered correct (see Boksem et al., 2011).

In the gambling section of the task, participants were given the opportunity to play a gamble on 75% of trials. They were forewarned on each trial about this by the presence of a specific visual cue, namely a pair of dice. On these trials, after receiving the feedback from the time estimation task (gain or loss), participants could choose to either play or pass on a mixed (50/50 chance, gain/loss) gamble. Playing the gamble led to two possible outcomes: 1) A win outcome which added €1.00, €1.20 or €1.40 to their overall experimental balance, or 2) a loss outcome which subtracted €1.00, €1.20 or €1.40 from this balance, dependent on the type of gamble offered (see Table 1). Alternatively, the participant could decide to pass on the gamble, thereby keeping the earlier gain or loss (i.e. +/- €1.20) from the time-estimation task. The gamble outcomes were independent from the performance on the time-estimation task.

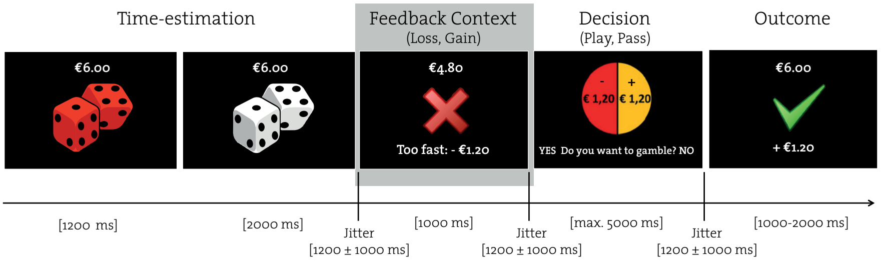

Fig. 1 Task design. The structure of a single trial is presented. Each picture represents a screen in the experiment. The trial started with a time-estimation task, where participants were required to press a button exactly 1 s after the dice colour changed to white. Feedback on performance was shown as a monetary gain of €1.20 if correct, or a loss of €1.20 if incorrect. Following this feedback, participants had the opportunity to choose a mixed gamble with a 50/50 chance to either gain or lose money. If participants decided to gamble, the gamble was played and the outcome then presented. Average duration of a trial is 9-13 s, jittered between time-estimation response and feedback context and decision screen. fMRI analysis was time-locked to the feedback onset prior to the gamble (grey shaded area).

All gamble outcomes (both gains and losses) immediately updated the total running balance for each participant. This balance was displayed on the screen at all times. Participants were informed that they would be paid this balance (if positive) as a bonus at the end of the experiment.

In the remaining 25% of trials, participants were not presented with a gamble after receiving feedback on the time-estimation trial. These “no-gamble” trials, indicated in advance by a specific visual cue (cubes instead of dice), were employed to potentially prevent participants using a fixed strategy, e.g. always or never gambling, and to enhance engagement in the gamble trials, as well as to allow for more rapid transitions through the sets of experimental balances. Time–estimation performance on these trials did however affect the experimental balance.

During the task we manipulated the experimental balance to create phases of “neutral” (total balance range of €-5 to €5), “negative” (range €-5 to €-17), and “positive” experimental balances (range €5 to €17) (For specific details about the phase transitions, see Boksem et al., 2012). The order of these three phases of experimental balance was counterbalanced. By adding these different phases we could also examine if this overall balance would affect individual risk preferences, in addition to the effect of immediate gains and losses incurred on that particular trial.

Each trial varied between 9-13 seconds, jittered (1200 ms ±1000 ms) between time-estimation response and the feedback context and the gamble presentation. The interstimulus-intervals are relatively short in comparison to other studies looking at brain responses reflecting subsequent behaviour. The rationale for using these short time-intervals was to ensure that the gain/loss feedback was as close in time as possible to the gamble decision, to ensure maximal framing impact. Moreover, by using multiple short random jitters, we reduce correlation between the different task phases and therefore improve the ability to tease these apart. In total, participants played on average 240 experimental trials (approximately 60 “no-gamble” trials (range = 42 trials, *SD* = 7.77) and 180 “gamble” trials (range = 24 trials, *SD* = 7.19). The design contained a nested structure including on average a total of 90 gain and 90 loss trials, these gain/loss outcomes were presented contingently on the participants’ behaviour. Within each set of these 90 trials, we had 30 negative EV, 30 zero EV, 30 positive EV gambles randomly presented. Within the 180 total trials 60 occurred with a positive running balance, 60 with a neutral running balance, and 60 with a negative running balance, counterbalanced across participant. The large amount of trials was employed to ensure adequate power to examine both play and pass decisions, since we cannot control participants’ choice behaviour. The task was presented in Presentation® software (Neurobehavioural Systems, Inc., Version 14). After scanning, the participants were debriefed.

Behavioural analysis

In order to assess the degree of risk-taking following gains and losses respectively, we used the percentage of gambles played as the dependent measure. We then performed a within-subject repeated measures ANOVA with 'feedback context' (loss, gain), and 'running balance' (positive, neutral, negative) and the 'gamble type' (+EV, 0EV, -EV) as independent variables. All behavioural analyses were performed in SPSS (IBM SPSS Statistics for Windows, Version 19.0.).

fMRI data acquisition and analysis

Imaging was performed at the Donders Centre for Cognitive Neuroimaging, Nijmegen, The Netherlands, using a 3-Tesla head-dedicated MRI system (Magnetom TrioTim; Siemens Medical Systems). Functional MRI (fMRI) images were acquired using a 32-channel head coil, with a standard multi-echo imaging pulse T2*-weighted sequence [field of view (FOV), 224 mm; 64 x 64 matrix; repetition time (TR), 2390 ms; echo times (TE), 9.4 ms, 21.2 ms, 33 ms, 45 ms, 56 ms; flip angle, 90°, 0.5 mm slice gap]. Using a multi-echo sequence provides a better signal-to-noise ratio for brain areas susceptible to dropout, while allowing for scanning of the whole brain (Poser et al., 2006). Thirty-one ascending slices were acquired (thickness of 3.0 mm; voxel size 3.5x3.5x3.0 mm) of the whole brain. High-resolution anatomical T1-weighted image (MPRAGE; 192 slices; TR 2300 ms, voxel size 1x1x1 mm) was acquired for anatomical localization. Participants' heads were lightly restrained with tape loosely placed on their head and the coil within the scanner in order to limit movement during image acquisition. The task consisted of a single run of 60 minutes; a standard high-pass filter (cut-off 128 s) was used during the GLM analysis to account for possible slow-frequency drifts.

fMRI data analysis was performed using SPM8 (Statistical Parametric Mapping; Wellcome Department, London, UK). Prior to preprocessing we combined and realigned the five read-outs acquired via the multi-echo sequence by using standard procedures described by Poser et al., (2006). Preprocessing consisted of realignment, slice-timing to the middle slice, co-registration of the functional images to the anatomical images, segmentation of the functional and anatomical image, and normalization to the Montreal Neurological Institute (MNI) template using the segmentation parameters. Functional images were then smoothed with a Gaussian kernel of 8 mm full-width at half maximum (FWHM). The first 30 volumes, acquired prior to task initiation, were used to estimate the weighted echo time per voxel for optimal echo combination (Poser et al., 2006) including allowing T1 equilibration effects, and discarded from the analysis. Motion parameters were stored and used as nuisance variables, including the quadratic effect and second derivatives, in the generalized linear model (GLM) analysis.

For the statistical analyses of the brain data, we performed a GLM for each participant consisting of four regressors of interest (1. Gain $_{Play}$, 2. Gain $_{Pass}$, 3. Loss $_{Play}$, 4. Loss $_{Pass}$) that were time-locked to the feedback of the time-estimation task (see Figure 1), with 'gain' and 'loss' referring to the time-estimation outcomes and 'play' and 'pass' to the participants' choice in the risk task. The GLM also included the regressors' temporal derivatives, and the eighteen motion regressors of non-interest. We also performed a GLM containing a breakdown of running balance (Positive, Neutral, Negative), feedback context (Gain, Loss) and decision (Play, Pass), resulting in 12 regressors. This GLM did not yield significant voxels nor cluster of voxels by adding the running balance. Moreover, with this analysis procedure six out of the 26 participants contained missing data points for the 12 regressors, resulting in a substantial loss of power. Additionally, the experimental running balance did not show a significant effect on behaviour, and all of the three gamble type conditions demonstrated similar behavioural effects on risk-taking. Therefore, and to maximize sensitivity in subsequent brain analysis, we collapsed across three running balance conditions and gamble type conditions for fMRI analysis. We performed a full factorial 2x2 analysis at the group-level, with *Feedback context* (loss, gain) as the first factor, and *Decision* (play or pass on gamble) as second factor. All reported coordinates are presented in MNI space.

Results

Behavioural data

Gambling behaviour following gains and losses

A significant main effect of feedback context (F (1,25) = 6.95, p = 0.01, η^2 = 0.22) was observed (Figure 2), that is, participants played the gamble significantly more after a prior loss (M = 46.2%, SE = 4.7, 95% confidence intervals (CIs) [36.6, 55.8]) than after a prior gain (M = 36.6%, SE = 4.3, 95% CIs [27.8, 45.5]). Participants were also sensitive to the expected values of the gambles, where participants decided to play the positive EV gamble the most and the negative EV gamble the least (M_{+EV} = 62%; M_{0EV} = 41%; M_{-EV} = 21%; F (1,24) = 23.73, p < .001, η^2 = 0.49). The expected value of the gamble did not affect risk preferences differently following gains and losses (Feedback context x EV gamble: F (2,24) = 2.44, p = 0.10, η^2 = 0.09).

The different phases of experimental running balance did not significantly affect behaviour ($M_{positive}$ = 40%, $M_{neutral}$ = 40%, $M_{negative}$ = 44%; F (1,24) = 0.88, p = 0.40, η^2 = 0.03), nor did it interact with the feedback context (F (2,24) = 3.27, p = 0.05, η^2 = 0.17). In line with the assumption that people evaluate risky choices with respect to small changes to their asset position (i.e. an immediate gain or loss), rather than their absolute total wealth (i.e. cumulative gains and losses; mental accounting: Kahneman & Tversky, 1979) we find that immediate gains or losses shift risk preferences.

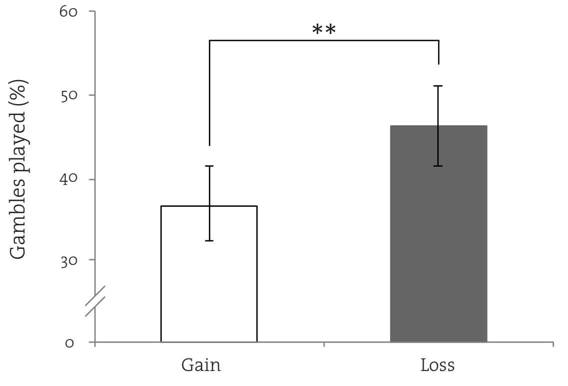

Fig. 2 Behavioural results. Mean percentage (estimated marginal mean) of trials in which participants chose to play a gamble after a loss (black bar, M = 46.2%, 95% CIs [36.6, 55.8]) and after a gain (white bar, M = 36.6%, 95% CIs [27.8, 45.5]), Error bars represent +- SE, ** p = .01.

Reaction times of decision to play or pass on a gamble following gains and losses

We tested whether type of decision and feedback context affected reaction times for decision to play or pass on a gamble, which could imply a difference in difficulty in processing the decision depending on the context. A main effect of type of decision on reaction times was found, F (1,25) = 5.49, p = 0.027, η^2 = 0.18, that is, participants who decided to play the gamble took significantly longer in confirming their choice than when deciding to pass on the gamble (M_{Play} = 1219 ms, SD = 332 ms; M_{Pass} = 1129 ms, SD = 306 ms). However, and importantly, there is no effect of the gain/loss feedback context on the decision time, F (1,25) = 0.03, p = 0.87, η^2 = .001, nor is there an interaction between feedback context and decision on reaction time, F (1,25) = 0.68, p = 0.42, η^2 = 0.03. Hence, the gain/loss feedback did not affect the how long participants took to make a decision to play or pass the gamble.

fMRI data

Feedback context (Gain and Loss) and Decision (Play or Pass)

We found expected brain response patterns for feedback to gains. Brain regions exhibiting increased activity for Gain as opposed to Loss feedback (Gain > Loss) were the bilateral dorsal striatum (putamen and caudate), PCC (posterior cingulate cortex), superior frontal gyrus (SFG) and activity in the mPFC, areas typically associated with reward processing. No suprathreshold voxels were found for Loss > Gain (see Figure 3a and Table 2 for details of areas). These analyses were corrected for multiple comparisons ($p_{FWE} < 0.05$, cluster voxels > 10).

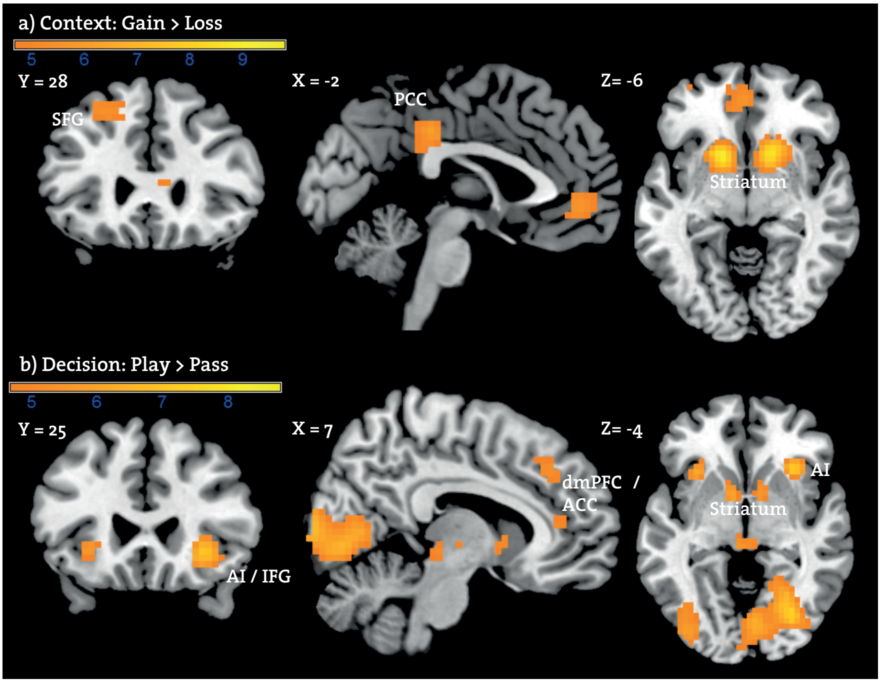

Fig. 3 fMRI activation to Context and Decision. a) Gain feedback > Loss feedback revealed stronger activity in the mPFC (-1,49,-5), PCC (-1,-32,38), MFG extending into SFG (-22,32,48), and bilateral striatum (-15,11,-8; 13,11,-8), see Table 1 for more details not shown here. There were no significant voxels for the context Loss > Gain. b) fMRI activation to Decision: Decision to play the gamble > decision to pass on the gamble showed increased dmPFC (6,35,38), ACC (10,39,10), AI overlapping IFG (31,25,-5; -33,21,-5), bilateral striatum (-8,7,-1; 10,11,-1), midbrain (-5,-28,-5) and visual cortex (27,-70,-8) to be increased. When participants decided to take the pass option (i.e. avoid risk) over the decision to play the gamble, an area consisting of the lateral parietal lobule / STG (45,-67,27) was increased (not shown here, for more details see Table 3). Thresholds are at $p_{FWE} < 0.05$ with extended threshold of > 10 voxels.

Table 2 Brain activations for Context (Gain, Loss)

Anatomy	Hemisphere	MNI			Clustersize	Z
	L/R	*x*	*y*	*z*	[voxels]	
Gain > Loss						
Putamen	L	-15	11	-8	149	Inf
Putamen	R	13	11	-8	166	Inf
PCC	L	-1	-32	38	53	5.68
MFG	L	-1	49	-5	90	5.27
Middle Frontal Gyrus	L	-22	32	48	53	5.18
IPL / Precuneus	L	-47	-60	41	81	5.09
Loss > Gain						
No suprathreshold voxels						

Note: Regions listed exceeded threshold of $p < 0.05$, family-wise corrected, with at least 10 contiguous voxels. Z-values for each peak are given. Abbreviations: L, left; R, right; Inf, Infinite; ACC, anterior cingulate cortex; IPL, inferior parietal lobule; MFG, medial frontal gyrus; SFG, superior frontal gyrus.

Comparing the decision to take risk with the decision to avoid risk (the main effect of decision, time locked to the feedback of the time-estimation task), we found increased activation of IFG extending into AI, and also in dmPFC extending into ACC, the striatum, midbrain, thalamus, and visual cortex. When participants chose to avoid risk, lateral parietal lobule extending into superior temporal gyrus (STG) (Brodmann area 39) showed increased activation (both at $p_{FWE} < 0.05$, cluster voxels > 10) (See Figure 3b, Table 3 for details of areas).

Context-dependent risky decision-making

To test how the observed preference shift towards risky choices in loss as compared to gain contexts is instantiated in the brain, we tested for an interaction between Feedback context (Gain, Loss) x Decision (Play, Pass): (contrast Gain $_{Pass}$ + Loss $_{Play}$) – (contrast Gain $_{Play}$ + Loss $_{Pass}$). The interaction revealed increased activity specifically in the ventral parts of the mPFC (cluster corrected on whole-brain for multiple comparisons, $p_{FWE} < 0.05$, with prior threshold of $Z > 3.21$, see Figure 4a and Table 4). This area is particularly active when individuals receive a gain and subsequently decide to choose the option to pass, as well as when they decide to play the gamble after receipt of a loss. We did not find any significant voxels that reflect to gain and loss feedback preceding the opposite behavioural performance: (Gain $_{Play}$ + Loss $_{Pass}$) - (Gain $_{Pass}$ + Loss $_{Play}$).

Beta values for each individual participant, extracted from the vmPFC cluster for each main regressor (Feedback context by Decision), showed an opposing response of the vmPFC for risk-taking following gains and losses respectively:

Table 3 Brain activations for subsequent Decision (Play, Pass)

Anatomy	Hemisphere	MNI			Clustersize	Z
	L/R	*x*	*y*	*z*	[voxels]	
Play > Pass						
Fusiform gyrus	R	27	-70	-8	1244	7.53
IFG / anterior Insula	R	31	25	-5	52	6.35
IFG / anterior Insula	L	-33	21	-5	27	5.67
Globus Pallidus	L	-8	7	-1	34	5.61
Caudate	R	10	11	-1	29	5.38
Midbrain / Thalamus	L	-5	-28	-5	35	5.11
IFG / dlPFC	L	-40	7	24	13	5.04
Superior Parietal Lobule	L	-29	-53	48	12	4.98
dmPFC / ACC	R	6	35	38	15	4.9
ACC	R	10	39	10	10	4.83
Pass > Play						
LPL / STG	R	45	-67	27	44	5.58
Lateral Occipital Cortex	L	-43	-77	31	10	5.11

Note: Regions listed exceeded threshold of $p < 0.05$, family-wise corrected, with at least 10 contiguous voxels. Z-values for each peak are given. Abbreviations: L, left; R, right; ACC, anterior cingulate cortex; dlPFC, dorsolateral prefrontal cortex; dmPFC, dorsomedial prefrontal cortex; IFG, inferior frontal gyrus; IPL, inferior parietal lobule; MFG, medial frontal gyrus; PCC, posterior cingulate cortex; LPL, lateral parietal lobe ; SFG, superior frontal gyrus.

relatively high vmPFC responses following gains were associated with subsequent safe choices (i.e. pass on the gamble), while relatively high vmPFC responses following losses were associated with subsequent risk-taking (see Figure 4b). Within the gain context, vmPFC activity significantly differed for Decision, with higher values for pass as compared to play (t (25) = 3.34, p = .003). For the loss context this pattern was reversed, showing higher values for play as compared to pass (t (25) = 2.54, p = 0.018). Activity for the decision to pass was significantly higher in the gain context then in the loss context (t (25) = 5.43, p < .001), with no significant differences in vmPFC response for the decision to play between the gain and loss contexts (t (25) = 0.71, p = 0.487) (see Figure 4b). To test whether observed differences in vmPFC activation truly resulted from differential processing of gain/loss information, without contamination from activity related to the subsequent choice, we performed a time-course analysis. Figure 4c illustrates the mean time course of the vmPFC cluster extracted from the interaction contrast for the four main regressors. For each participant, we ran a

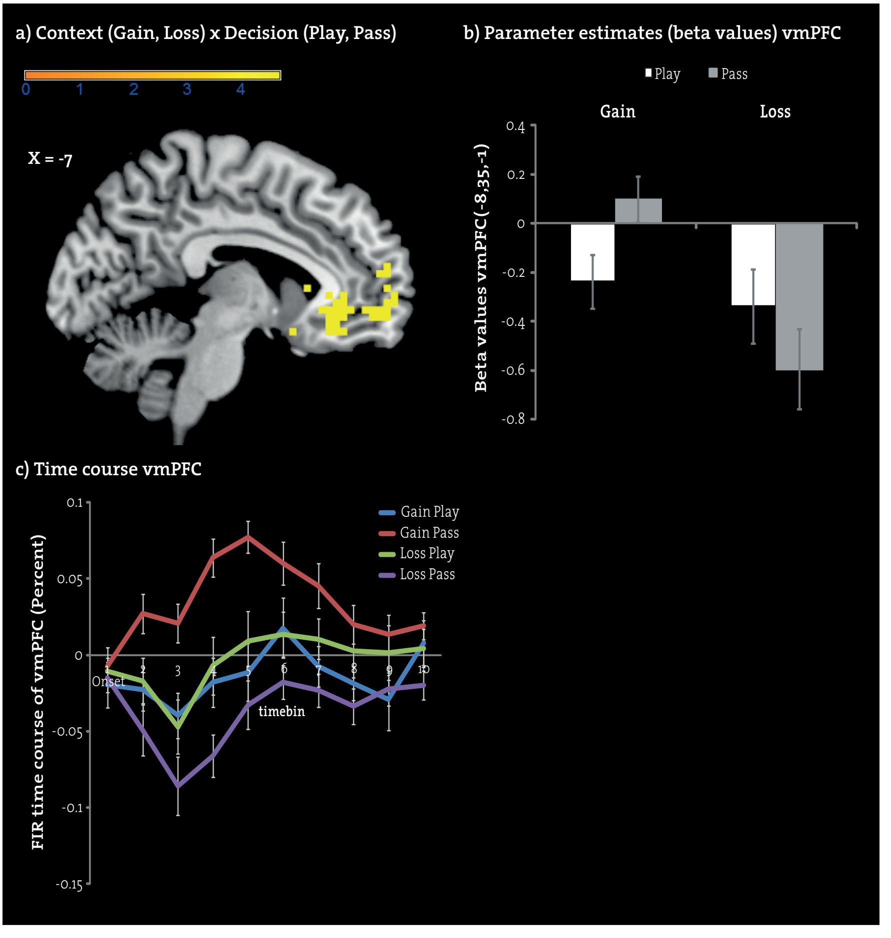

Fig. 4 a) fMRI activation maps of the interaction contrast Context x Decision [(Loss $_{Play}$ + Gain $_{Pass}$) - (Loss $_{Pass}$ + Gain $_{Play}$)]. The activation patterns show a cluster of vmPFC (sgACC extending into mPFC (-8,35,-1)) activity correlating to subjects' behavioural tendency to choose to play the gamble after they have experienced a small loss, and to pass on the gamble when they have experienced a small gain. Cluster-level $p_{FWE} < 0.05$ on whole-brain, with extended threshold > 100 voxels at Z>3.21. b) Parameter estimates (beta values) of vmPFC for context (Gain, Loss) by decision (Play, Pass). c) Time series of the vmPFC of each regressor from the interaction contrast. The time courses were estimated with the finite impulse response model from the onset of the delivery of the gain/loss feedback, for a length of 24s. A significant difference between gain and loss feedback and the decision to play and pass on the gamble is shown from timebin 2 (~2.4 s after feedback onset). See Table 5 for detailed statistics. Error bars show ± SE.

Table 4 Brain activations for the interaction Feedback Context (Gain, Loss) x Decision (Play, Pass)

Anatomy	Hemisphere	MNI			Cluster size
	L/R	x	y	z	[voxels]
vmPFC/sgACC	L	-8	35	-1	226

Note: Regions listed exceeded threshold of $p < 0.05$, family-wise corrected on cluster-correction of whole-brain, with at least 100 contiguous voxels. Abbreviations: L, left; sgACC, subgenual anterior cingulate cortex; vmPFC, ventromedial prefrontal cortex.

single finite impulse response (FIR) time course model on the vmPFC for a length of 24 seconds, creating 10 time bins each with a length of one TR (2.39 s). This analysis showed that vmPFC responses following gains and losses differed between decisions to play or pass already within one TR after the feedback onset (Between Play-Pass: $t_{bin2}\,(25) = -4.429$, $p < .001$ following the gains, and $t_{bin2}\,(25) = 2.046$, $p = 0.051$ following losses, between Gain-Loss for decision to Pass: $t_{bin2}\,(25) = 3.525$ $p = .002$, and for decision to Play: $t_{bin2}\,(25) = -0.243$, $p = 0.810$), indicating that it is the differential processing of gains and losses that drives subsequent choices (also see Figure. 4c and Table 5).[1]

The processing of gains and losses could of course potentially be affected by the outcome of the gamble. To investigate this, we ran a separate GLM to analyse the BOLD response to feedback processing based on the outcome of the gamble. This GLM contained the regressors for Feedback context (gain, loss) by Gamble outcome (won, lost) time-locked to the feedback context onset. This GLM also included a regressor for the Gamble outcome (won gamble, lost gamble, no gamble) time-locked to the gamble onset, and 18 realignment parameters of non-interest. This analysis showed no significant differences in gain and loss processing related to the outcome of the gamble. Furthermore, we also investigated whether the BOLD response of the vmPFC observed for the interaction contrast (feedback context by decision) could reflect the signal of the event preceding the receipt of the gain and loss outcome (i.e. white dice cue). We ran an additional GLM analyzing the BOLD response to the onset of the white dice cue based on interaction contrast feedback context by decision. The interaction did not reveal any significant voxels or cluster of voxels at the onset of the white dice cue.

1 The FIR model estimates an average effect of the vmPFC seed region, at the time of the onset of the feedback onset. The model assumes that overlapping hemodynamic response functions linearly add up. Therefore, the current time course can contain some activity related to the onset of the decision event, because of the short interstimulus-interval. However, in addition there is a trial-by-trial short, however randomly jittered interval in between the feedback context and decision event, the time-course would mostly reflect the pattern of the vmPFC response towards the onset of the feedback outcome.

Table 5 Statistics of paired t-tests of the vmPFC time course

Contrasts	Gain Play - Gain Pass		Loss Play - Loss Pass		Gain Pass - Loss Pass		Gain Play - Loss Play	
Time bin (TR)	*t (25)*	*p-value*	*t (25)*	*p-value*	*t (25)*	*p-value*	*t (25)*	*p-value*
1	-0.840	0.409	0.469	0.643	0.500	0.621	-0.550	0.587
2	-4.429	<0.001	2.046	0.051	3.525	0.002	-0.243	0.810
3	-3.559	0.002	2.205	0.037	5.505	<0.001	0.326	0.747
4	-4.080	<0.001	3.036	0.006	7.821	<0.001	-0.431	0.670
5	-4.429	<0.001	1.838	0.078	6.824	<0.001	-0.744	0.464
6	-1.973	0.060	1.481	0.151	5.160	<0.001	0.155	0.878
7	-2.706	0.012	1.830	0.079	3.694	0.001	-0.770	0.449
8	-2.158	0.041	1.732	0.096	2.615	0.015	-0.975	0.339
9	-1.694	0.103	1.148	0.262	2.134	0.043	-1.023	0.316
10	-0.551	0.587	1.619	0.118	2.595	0.016	0.197	0.846

Note: The onset (time bin 1) is time-locked at the feedback delivery of the time-estimation over a time period of 24 s (10 TR time bins). Results obtained from a repeated measures ANOVA testing the interaction contrast for each time bin separately and adjusted for multiple comparisons using a Bonferroni adjustment resulted in the same results as presented in the above table conducted with t-tests.

Hence, the results show that the vmPFC is associated with context-dependent risky decision-making, broadly following the observed behavioural choices.

Discussion

The current study identified brain mechanisms that are engaged in the evaluation of monetary gains and losses, showing that these areas are associated with patterns of risk preference, even though these choice patterns are inconsistent with classical economic models of decision-making. Exploring the brain mechanisms that underlie how gain/loss contexts can lead to a switch between risky or safe choices when presented with the same gamble can provide useful insights into how valuation processes can exert a strong effect on our evaluation of risk, and in turn on the likelihood of players to select risky or safe choice options.

Here, we showed that participants' risk attitudes for identical mixed (50-50, gain-loss) gambles were significantly affected by the receipt of either a small monetary gain or a loss immediately prior to the risky decision itself. Interestingly, and importantly for theories of economic preference, this effect was evident even within subjects, with our participants displaying inconsistent risk patterns, for the identical sets of gambles, across the entire span of the experiment. As expected, and in line with previous literature on preference shifts for risk (Tversky and Kahneman, 1979, 1981, 1992; De Martino et al., 2006; Tom et al.,, 2007; Xue et al.,, 2011), participants who had experienced a gain typically decided to subsequently choose the safer option (i.e. passing on the gamble), thereby showing an aversion to risk. In contrast, when participants had just experienced a loss they showed a shift in preference towards the risky gamble, now exhibiting increased risk-seeking tendencies as compared to when gains preceded the choice. Additionally, these effects were observed using real, consequential choices, where decisions were paid out at the conclusion of the experiment, in contrast to other studies that have used either hypothetical rewards (Gonzalez et al., 2005) or chosen one trial at random for payment (Venkatraman et al., 2009; Porcelli & Delgado, 2009; Christopoulos et al., 2009 (exp. 2); Sokol-Hesner et al., 2012a (selecting 10 random trials)). In the current study the context induced by the time-estimation feedback is a monetary gain or loss and always associated with either successful or unsuccessful performance on the task.

In terms of brain activation, we found significant reward-related activity for gains as compared to losses in bilateral dorsal striatum, mPFC, SFG, and precuneus. These areas are consistent with those previously found for reward-related activity (Breiter et al., 2001; Delgado et al., 2003; Elliott et al., 2003; Tom et al., 2007). We did not find any significant differences in BOLD response for losses as compared to gains at this time point. Previous studies have reported increased activity in areas such as AI, amygdala, ACC, and lOFC while evaluating losses, implicated as a function of negative stimulus aversion, error detection, or loss aversion (Breiter et al., 2001; Paulus et al., 2003), though these activations are not always observed (Seymour et al., 2007) and have even shown to overlap to some extent with the receipt of rewards as well as of punishments (Bartra et al., 2013).

Also in accordance with previous work, a significant main effect in the BOLD response for the choice to play as opposed to pass on the gamble was observed in the dmPFC/ACC, AI overlapping IFG, IPS, caudate, and thalamus. A large number of studies have reported activity in these areas correlating with risk-taking behaviour (e.g. Paulus et al., 2003; see Mohr et al., 2010 for overview). Conversely, when participants chose to pass on the gamble, hence avoiding subsequent risk, increased activity of the lateral parietal lobule and STG (BA 39) was observed. These areas have been previously associated with promoting safe behaviour over risk-taking, and have been reported when selecting a safe over a risky option (Matthews et al., 2004).

The primary goal of the study was to determine how the evaluation of prior gains and losses may affect preferences for risk, as has been shown behaviourally, by studying the underlying neural mechanisms associated with the evaluation and integration of gain and loss information which in turn can potentially predict risk preferences. We hypothesized that when experiencing gains and losses we engage in value-computation and integration of these appraisals, and when a subsequent gamble is offered these processes have a differential impact on preferences for risk.

Supporting this hypothesis, we found a strongly significant interaction between the monetary outcome of the previous - unrelated - time-estimation task (i.e. gain or loss) and the subsequent decision to play or pass on the gamble in the risky decision task. This interaction was associated with enhanced activation in the ventral part of mPFC. This vmPFC region responded more strongly when individuals experienced a €1.20 gain prior to selecting a safe option (i.e. passing on the gamble and accepting the current state) as compared to selecting a risky option (i.e. playing a mixed "double-or-quits" gamble). Conversely, the same area responded more strongly at the time individuals experienced a €1.20 loss, though only when they then decided to select the risky option as compared to selecting the safe option. Importantly, this interaction was found within-subjects for identical sets of choices, that is, when the gambles comprised of the same probabilities and outcomes, and was in line with the observed decision behaviour; choosing the safe option to retain the gain, and choosing to play the gamble to compensate for the loss. These results therefore suggest that the same area that has previously been shown to be important for encoding value, regulation, and control of affect and guidance of subsequent choice behaviour (Urry et al., 2006; Koenigs & Tranel, 2007; Hare et al., 2009; Rushworth et al., 2011; Sokol-Hessner et al., 2012a; Rosenbloom et al., 2012) is also associated with preference for either taking or avoiding risk depending on the current context.

A plausible explanation for these findings is that the vmPFC functions in a regulatory capacity, providing a mechanism to allow for adaptive decision-making behaviour as a function of the current (monetary) context, that is, one of gain or loss. Greater contribution of the vmPFC when experiencing a gain stimulated safer subsequent behaviour, suggesting an inhibition of the temptation to gamble, hence 'locking-in' the current gain. When experiencing a loss, the contribution of the same area switches, and now greater activation stimulates riskier behaviour, potentially as a means to attempt to recover from the prior loss and break-even on the trial. The vmPFC seems thus to respond differently as a function of whether the current context is one of immediate gains or losses, consistent with its role in value encoding. In other words, these results suggest that vmPFC may not be solely tracking and evaluating how desirable a current outcome and subsequent risky choice is, but rather that it may be executing a more complex function: assessing the specific choice response (play or pass behaviour) that seems most adaptive given the particular situation. By "adaptive" here we refer to the ability of individuals to flexibly adapt their preferences in order to obtain a particular outcome that is most valued at the given time, and which is reflected in their decision behaviour itself.

An alternative explanation for the current findings is that when vmPFC responds more strongly towards the gain or loss, in a positive and negative way respectively, then safer rather than risky behaviour is more valued. When the vmPFC response for the same gain or loss is relatively weak, risky behaviour follows. This explanation would suggest that the vmPFC may engage control or regulatory strategies that inhibit risk-taking, and when this control is absent then there is the temptation to gamble. However, brain activity observed at the cue preceding the feedback does not seem to support this explanation, as these results did not reveal overlapping significant voxels with the observed clusters for the feedback processing, nor did it reveal significant voxels of regions associated with affective nor cognitive control. Previous research has implicated the dlPFC in reflecting flexibly adaptive behaviour, via a strong indirect coupling with the vmPFC (Hare et al., 2009; Christopoulos et al., 2009). The dlPFC, implicated in self-control and impulsivity, indirectly modulates the vmPFC value signal to guide goal-directed behaviour (Hare et al., 2009). The relatively weak valuation signal of the vmPFC prior to the decision to play the gamble may be a result of a lack of self-control and therefore modulation by the dlPFC on the value signal of the vmPFC, resulting in choosing to play the gamble. It would be interesting to examine how self-control may interact with gain/loss contexts for risky choice sets in guiding risky choice.

The current results extend our knowledge of vmPFC functioning in decision-making, supporting previous work suggesting this area is involved in several processes in addition to pure value computation. For example, this area has been shown to be active during emotion regulation and extinction to aversive stimuli (Phelps, Delgado, Nearing & LeDoux, 2004; Urry et al., 2006). Other studies have also reported a role of the ventral parts of the forebrain in behavioural and affective control (O'Doherty et al., 2003; Di Pellegrino et al., 2007; Etkin, Egner, Peraza, Kandel & Hirsch, 2006; Etkin, Egner & Kalisch, 2011; Roy, Shohamy & Wager, 2012). Additionally, lesion studies have shown that patients with vmPFC damage were unable to evaluate and integrate so-called 'somatic markers', hypothesized to be an affective response to aversive stimuli, when attempting to choose from advantageous and disadvantageous options when playing the Iowa gambling task (Bechara et al., 1994). In other studies, vmPFC patients showed increased risk-taking following losses, a behaviour which they were unable to inhibit (Sanfey et al., 2003; Shiv et al., 2005), and an insensitivity to differences in expected value between choices of gains and losses (Weller et al., 2007; Clark et al., 2008). The above studies support an important role of the vmPFC in integrating contextual appraisals (gain or loss) and linking this to specific patterns of behaviour and autonomic responses (Rosenbloom et al., 2012; Sokol-Hessner et al., 2012b).

In short, we show here that risk-taking behaviour is strongly modulated by the gain or loss context of the decision. This modulation has its neural basis in the vmPFC, which appears to integrate and represent the contextual value of a stimulus in light of subsequent choice in order to adaptively guide the decision-making process for risky prospects. That is, vmPFC activation supported safe behaviour after a monetary gain, and risky behaviour following a monetary loss. How the integration of decision context (i.e. gain and loss) by the vmPFC may vary by different expected values of gambles is still an interesting open question for understanding the adaptive role of the vmPFC in combining the different values in guiding risk behaviour. The current design does not allow us to disentangle whether the behavioural effects are driven more by the receipt of monetary gains/losses or by performance-based success/failure independent of monetary reward. For future studies, it would be interesting to test whether the behavioural effects are specific for performance feedback or for the receipt of monetary reward.

In conclusion, our study extends the existing literature by examining the specific brain networks involved in risky decision-making involving gains and losses. At the same time it emphasizes the importance of disentangling the different phases of the decision-making process. Finally, our study demonstrates that choice cannot be studied in isolation, but that the broader context the choice is placed in has an important role to play.

3

The effect of positive and negative feedback on risk-taking across different contexts

Abstract

Generally people avoid gambles with mixed outcomes due to loss aversion. In fact, preferences for risky choices have been well established as unstable and context-dependent. It has been demonstrated that gain/loss outcomes influence subsequent risk preferences. That is, people typically prefer risky options after a financial loss, while generally preferring safer options after a monetary gain. However, these gain/loss outcomes can be confounded by participants' performance, and therefore it is unclear whether these effects are purely driven by monetary gains/losses, or rather by success or failure at the task. In this study we therefore separated monetary gains/losses from performance success/failure prior to a risky choice. Participants performed a task in which they experienced different types of contexts: 1) monetary gain or loss received based on participants' performance, 2) a pure monetary gain or loss that was randomly rewarded, and crucially independent from performance, and 3) success or failure feedback based on the participants' performance, but without any monetary incentive. Immediately following a positive/negative context, participants decided to either play or pass on a monetary gain-loss gamble. If played, outcome of the gamble would be presented and added to the participants running balance. If decided to pass on, nothing would happen. We found that risk preferences for identical sets of gambles were biased by positive and negative contexts containing monetary gains and losses, but not by contexts containing performance feedback independent of monetary feedback. This data suggests that the observed framing effects are driven by aversion for monetary losses and not simply by the valence of the context. Furthermore, the lack of framing following pure performance feedback suggests that positive or negative moods do not underlie framing effects. These results highlight the specific context dependency of risk preferences.

Based on: Losecaat Vermeer, A. B. & Sanfey, A. G. (*under revision*). The effect of positive and negative feedback on risk-taking across different contexts.

Introduction

We often make decisions that entail some level of uncertainty about what the final outcome will be. For example, choosing which restaurant to pick for dinner, deciding to place a bet on who will win the World Cup, or whether to go on a blind date. It has been found that in general people dislike risky or uncertain outcomes (Tversky & Kahneman, 1981, 1992). For example, when offered a choice between a certain €10, or to play a gamble to win either €20 or €0 with equal probabilities, the vast majority of people choose the certain €10 option. In fact, our preferences for risky choices have been well established as unstable and context-dependent. Whether or not we place a large bet to win the World Cup pool may depend on whether we have just won or lost money, even though the current bet is independent of this previous outcome. Similar behavioural effects have been observed in many everyday scenarios, such as in trading (Brown et al., 1996), betting at racetracks (Hausch et al., 1981), health decisions (Levin et al., 2002), as well as with clinical populations (Campbell-Meiklejohn et al., 2008).

Research has shown that choices between relatively risky and relatively safe options made immediately after experiencing a financial loss, typically lead to a higher preference for the riskier options (Tversky & Kahneman, 1992; Barkan & Busemeyer, 2003; Xue et al., 2011; Hytönen et al., 2014). For example, one study (Xue et al., 2011) showed that deciding to either play or pass on a gamble was influenced by the outcome of prior gambles. Participants decided to play the gamble more often following a loss on the previous gamble trial as compared to a win beforehand. In a prior study by our group (Losecaat Vermeer et al., 2014) we found individuals' risk preference to be sensitive to a preceding monetary gain and loss outcome. These gain and loss outcomes were based on correct or incorrect performance respectively on a time-estimation task. Importantly, these performance-based monetary gain/loss outcomes were unrelated and independent of subsequent gambles. Immediately following these gain/loss outcomes, individuals decided to play or pass on a 50-50 mixed (gain-loss) gamble. We found that individuals chose the gamble more often after receiving the performance-based monetary loss than after receiving a performance-based monetary gain. In other words, outcomes independent of the decision at hand (e.g. recent gains or losses) can influence risk preferences in determining our choices.

In the aforementioned studies, shifts in risk preferences following monetary gain and loss contexts were also related to the outcome of players' actions. In other words, outcomes were based on either the individuals' decision to play a gamble previously (Barkan & Busemeyer, 2003; Xue et al., 2011), or were based on the individuals' actual performance on an unrelated task (Losecaat Vermeer et al., 2014). Hence, the observed behavioural effects on gambling behaviour following gain/loss outcomes could be related to either the monetary outcomes or to the performance measures themselves (i.e. whether the task was a success or a failure). In the current study, we aimed to clarify whether gain/loss context effects are driven by monetary feedback or by performance-based feedback.

Pure monetary gain and loss outcomes have previously been shown to affect risk preferences for gambles. The susceptibility to pure monetary gains and losses have been most strongly observed for mixed gambles, that is, those offering a chance to both win and lose money, such as a 50/50 chance to either gain €50 or lose €50. People typically choose to avoid playing such gambles, even when the expected value is equal to or even higher than the option to not play the gamble. This behaviour has been explained by the concept of loss aversion of Prospect Theory (i.e. peoples' greater sensitivity to losses than to gains of equivalent value) (Kahneman & Tversky, 1979; Tversky & Kahneman 1992). This also holds for choice outcomes that have been framed as either gains or losses of equal expected values. For example, given a choice between keeping €20 out of a €50 for certain, or a gamble with an opportunity of keeping the total €50 or instead keeping nothing (i.e. gain frame), people prefer the certain €20. Conversely, when offered a choice between accepting a loss of €30 out of a €50, or gambling with a risk of losing the total €50 or losing nothing (i.e. loss frame), people tend to prefer the gamble (framing effect, Tversky & Kahneman, 1981). Thus, pure monetary gains and losses affect risk preferences. However, whether pure monetary gains/losses independent of active choice affect risk preferences in a similar direction is unclear.

Evaluation of rewards and punishments, or performance-based success and failure, usually informs us whether to continue or adapt behavioural strategies (Barto & Sutton, 1997). It is to date less clear whether performance feedback *per se* influences subsequent risk in a similar direction as pure monetary feedback. Earlier functional neuroimaging findings suggest that performance-based feedback might recruit similar processes to monetary feedback. For example, positive performance feedback has been found to induce appetitive motivational behaviour similar to monetary rewards (Daniel & Pollmann, 2014; Delgado, Stenger & Fiez, 2004), with the latter shown to be also associated with financial risk-taking (Knutson et al., 2001; Kuhnen & Knutson, 2005). Negative feedback (i.e. errors or failures in performance) has been found to recruit brain structures also related to the salience and avoidance of aversive outcomes and fear (Carter et al., 1998; Breiter et al., 2001; Shackman et al., 2011; Tom et al., 2007). These studies suggest that different types of contexts might be based on the same psychological processes. However, it is unknown whether these effects extend to choice outcomes occurring in a different context, for instance, whether successful performance can enhance subsequent risk-taking by reinforcing reward-seeking, or whether failure feedback would signal avoidance of bad outcomes in the context of monetary losses.

There are a few studies that have demonstrated preference shifts for financial risk following unrelated, non-financial, outcomes (Knutson, Wimmer, Kuhnen & Winkielman, 2008; Stanton & Reeck, 2014). For instance, incidental mood, induced via affective stimuli, has shown to influence risk preferences for mixed gambles (Knutson et al., 2008), as well as enhance monetary framing effects (Stanton & Reeck, 2014). Positive arousing stimuli (i.e. erotic pictures), unrelated to the task at hand, increased participants' preference for a high risk option, but the effect was not observed following display of neutral (i.e. household appliances), or negative pictures (i.e. snakes or spiders) (Knutson et al., 2008). Similar behavioural results were found for framing effects involving monetary gains or losses, with accentuated framing effects found following positive film clips (i.e. inducing happiness) as compared to negative film clips (i.e. inducing sadness). These studies indicate that preference shifts for monetary risk are highly context-dependent and can be influenced by loss aversion, but also by mood effects. Performance-based feedback prior, but unrelated, to the choice might affect risk preferences in a similar vein as these unrelated, non-financial, outcomes.

The current study directly compares performance and monetary contexts prior to, and independent of, identical mixed gambles. The aim of this study is to examine whether context-dependent preference shifts that were observed for mixed gambles following performance-based monetary rewards and punishments (Losecaat Vermeer et al., 2014), are purely driven by the receipt of monetary gains/losses, or rather by performance-based success/failure feedback, independent of monetary reward. This will provide a more thorough understanding of how risk preferences may be altered by different, unrelated, contexts, and specifically gain a better idea of the possible role of loss aversion underlying each type of context. To examine this question, participants were presented with identical sets of mixed gambles following different types of positive and negative feedback. We investigated three different types of contexts: 1) monetary gain or loss based on participants' performance, as in our previous study (Losecaat Vermeer et al., 2014), 2) a pure monetary gain or loss that was randomly distributed, and crucially, was independent of performance, and 3) success or failure feedback based on the participants' performance, but without any monetary consequence. Immediately following each of the aforementioned context types, participants decided to either play or pass on a mixed gamble, offering a monetary gain with a probability of 0.5, and a monetary loss with a probability of 0.5. If they chose to play, the outcome of the gamble would be presented and added to the participants running balance. If they decided to pass on the gamble, the next trial would immediately begin.

Based on prior work (Losecaat Vermeer et al., 2014), we expected performance-based monetary gains/losses to influence risk preferences, that is, increased risk-taking following a monetary loss, and decreased risk-taking following a monetary gain. Based on loss aversion, we hypothesized that individuals also increase risk-taking, after receiving randomly distributed losses versus gains. However, we expected that the behavioural effect observed for performance-based gain/loss outcomes might be even stronger than after incidental monetary gain/loss outcomes. Monetary gains/losses that are earned (by performance) might enhance the sensitivity to losses (i.e. endowment effect; Thaler et al., 1980) as compared to incidentally receiving monetary gains/losses. Furthermore, we explored whether performance success and failure feedback influences risk preferences for monetary gambles. We speculate that if performance feedback does not affect risk preferences differently, then the observed framing effects in the previous study are purely driven by monetary gains/losses, and not, or less, by unrelated contexts, such as mood effects potentially induced by successful or unsuccessful performance (Henkel and Hinsz, 2004).

Materials and Methods

Participants

A total of 75 undergraduate students participated in the study. All gave written informed consent and either received research credits for participation or were financially compensated via a flat fee (10 Euro) for completion of the task. They also had the opportunity to win a bonus in addition to the participation fee, up to a maximum amount of 10 Euro. Exclusion criteria were self-reported regular drug use of marijuana, or use of psychotropic drugs. Three participants were excluded as they did not respond to a substantial number of trials (>20%). Data is therefore reported from 72 participants (Men = 21, M = 21.86 years, SD = 3.46). The study was approved by the local ethics committee.

Task design and procedure

We adapted a previous paradigm (Losecaat Vermeer et al., 2014) in order to study risk-taking behaviour in the context of prior rewards and punishments of different types. The task contained three different experimental trial type conditions; monetary trials, performance trials, and combined performance/monetary trials.

Each of these trials was designed to induce either a positive (reward) or negative (punishment) context. In the monetary trials, either a positive (+€1.20) or negative (-€1.20) monetary amount was randomly awarded on each trial. In the performance trials, participants were told they had either successfully or unsuccessfully completed a simple task. And finally, in the combined trials, participants saw both performance feedback as well as monetary feedback, with successful performance accompanied by a monetary reward (+€1.20) and failure accompanied by a monetary punishment (-€1.20).

In the monetary condition, each trial began with a pair of dice displayed on the screen. Based on the total sum of the dots visible on the dice, participants would either win or lose €1.20. If the total sum of dots was between 7-12 participants would win €1.20, however, if the total sum of dots was 2-6 they would lose €1.20. The total sum of dots on the dice was presented randomly on each trial, to ensure approximately 50% wins and 50% losses.

In the performance condition, each trial began with a time-estimation task in which participants received feedback based on their ability to successfully estimate a time duration of a second, adapted from a previous paradigm (Losecaat Vermeer et al., 2014). Each trial began with a pair of red dice that changed colour to white. When the dice turned white, participants were then required to respond exactly one second later by pressing a key. If they responded within an allowable window then the trial was a success, otherwise it was a failure. The purpose of the task performance trials was to induce either a positive or negative context, that is one purely based on performance and not monetary reward, to enable a test of whether subsequent shifts in risk behaviour are driven by task performance-related success or failure.

In the combined trial type condition, we used the same paradigm that was for the performance condition, with the addition of monetary feedback. That is, if the time-estimation task was successfully performed participants additionally received a monetary reward and if unsuccessful on the time-estimation task then participants took a monetary loss, identical to the original paradigm (Losecaat Vermeer et al., 2014).

In all the three trial type conditions, immediately following the positive and negative feedback contexts described above, participants then were shown a mixed (50/50 chance, gain/loss) gamble (see Figure 1), which they could decide to either play or pass. If they decided to pass on the gamble the trial immediately ended. However, if they decided to play, the gamble was resolved and the corresponding win or loss amount was added to their total experimental balance. Participants did not see this running balance until the end of the experiment, and had been informed that they would be paid this balance (if positive) as a bonus.

The mixed gamble contained either a positive expected value ('+ EV'), a negative expected value ('- EV'), or a zero expected value ('0 EV') by varying the gain or loss outcome from €1.00, €1.20, to €1.40 as compared to the 'pass' option (i.e. choosing to keep the €1.20 gain or loss) (see Table 1). We created these three different gamble types to assess whether participants were attending to, and sensitive of, the expected value of the gamble.

Table 1 Mixed gambles by expected value (EV) and EV type.[a]

50|50 mixed gamble	Expected value (EV)	Gamble type
- €1.40 | + €1.20	-0.10	- EV
- €1.20 | + €1.00	-0.10	- EV
- €1.20 | + €1.20	0	0 EV
- €1.00 | + €1.20	0.10	+ EV
- €1.20 | + €1.40	0.10	+ EV

[a] All gambles contained of a 50-50 probability to lose-win money

In addition, we included a control trial, which served to measure participants' baseline risk level. Each control trial began with a pair of blue dice that changed colour to white. Participants were required to watch these cues and not respond, similar to the monetary condition. However, participants did not receive any feedback following these cues. After the presentation of the white cue, participants received a mixed gamble which they could decide to either play or pass, identical to the other three conditions as described above (Figure 1).

Procedure

Participants first performed two short practice sessions. In the first session participants practiced the time-estimation trial. Here, participants were required to estimate a one-second time duration. After a cue on the screen changed in colour, they were instructed to wait exactly one second and then press a response button, with their precise response times recorded. We used the minimum and maximum of these recorded response times to determine an initial allowable response time-window for the performance-based trials in the experiment. The second practice session gave participants the opportunity to observe the gambling task and experience the different trial type conditions. After these practice sessions, the experiment lasted for approximately 30 min including a short break halfway through the task.

Before beginning the task, participants were instructed that their goal was to win as much money as possible, and that their final balance would be paid out as a bonus (with a maximum amount of €10) in addition to their participation fee (a flat fee of €10, or participation credits) for completion of the task. Hence, participants' total payment at the end of the experiment would range between €0 and €10 if they participated for credits, and between €10 and €20 if they

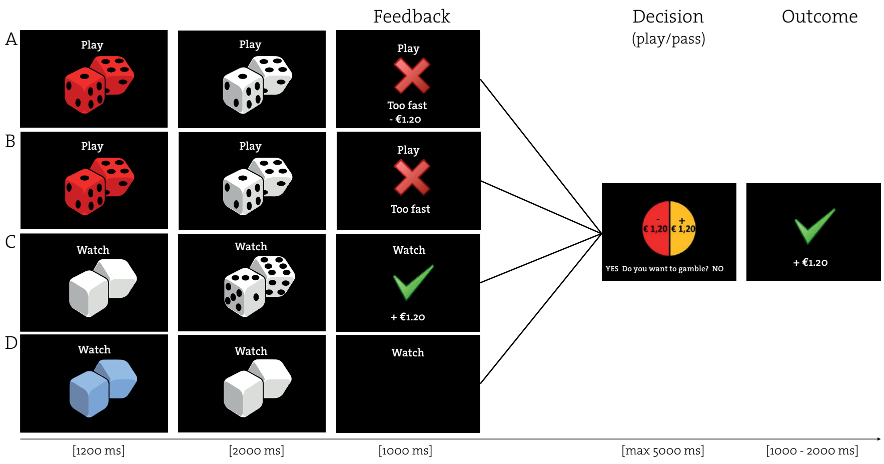

Fig. 1 Task design, showing Play and Watch trials. Each picture represents a screen in the experiment. A) The combined monetary and performance (MP) trial; Trial began with a time-estimation task, where participants were required to press a button exactly 1 s after the red dice changed in colour to white. Feedback on performance was given as "Correct" with a monetary gain of €1.20, and if incorrect as "Too fast" or "Too slow" with a loss of €1.20, B) The performance (P) trial; Trial structure was the same as A. However, only success and failure feedback on performance was given, as "Correct" and if incorrect as "Too fast" or "Too slow", C) The monetary (M) trial; Trial began with a white cue that changed to a pair of dice. Participants only had to passively watch, as instructed on top of the screen. They were instructed that if the total sum of dots on the dice was higher than 6, participants gained €1.20, if the total sum of dots was 6 or less, the participant lost €1.20, D) Control trial; Trial began with a blue cue that changed in colour to white. Participants only had to passively watch, as instructed on top of the screen, no feedback or incentive was given. For all trial types, immediately following feedback or no feedback (i.e. D), participants had the opportunity to choose to play or pass on a mixed gamble with a 50/50 chance to either gain or lose money. If participants decided to gamble, the gamble was played and the outcome was presented. Average duration of a trial is 9-13 s.

participated for money. At the start of each trial, participants saw a visual cue with the instruction to either "Watch" or "Play". When it said "Watch", participants were required to just watch the screen and see the cue change to either a different colour (control trial), or to a pair of dice (money trial). Depending on the total sum of dots on the dice, participants won or lost money (see task design). When the trial said "Play" participants were required to perform a time-estimation task, that is, they had to press a response button exactly one second after a red cue changed colour to white (Figure 1). Responses on this time-estimation task were considered correct when they were within an allowable time-interval. For correct responses, participants received positive feedback either in the form of "correct" (task performance trial) or in the form of "correct" including a gain of €1.20 (combined trial). When a response was not within this time-interval, participants either received negative feedback as "too fast" or "too slow" (task performance trial), or received the same negative feedback with an additional loss of €1.20 (combined trial).

The allowable response-interval of these "Play" trials was initially calculated based on their performance in the practice run and then covertly adjusted throughout the task as a function of the variance in response time of the participant, in order to ensure an equal number of positive and negative feedback on this task. Therefore, if participants responded within the allowable response-interval, this interval was subsequently shortened by 50 ms; if they responded either too quickly or too slowly, the interval was then lengthened by 50 ms. Importantly, although the amount of positive and negative feedback was manipulated, the feedback was contingent upon participants' performance. Thus, the time-interval was adjusted individually based on the participant's actual response behaviour (see Boksem et al., 2011).

Immediately following the feedback on both the "Watch" and "Play" trials, participants could choose to either play or pass on a mixed (50/50 chance, gain/loss) gamble. Playing the gamble led to two possible outcomes: 1) A win outcome which added €1.00, €1.20 or €1.40 to their overall experimental balance, or 2) a loss outcome which subtracted €1.00, €1.20 or €1.40 from this balance, depending on the type of gamble offered (see Table 1). Alternatively, the participant could decide to pass on the gamble, thereby keeping the earlier monetary gain or loss (i.e. +/- €1.20) in case of the money and combined trials. The gamble outcomes were independent from the performance on the time-estimation task and the outcome of the money trials. All gamble outcomes (both gains and losses) immediately updated the total running balance for each participant.

In addition to the four trial types discussed, 12.5% of the total trials were "no-gamble" Play trials. In these trials, participants were not presented with a gamble after receiving feedback on the time-estimation trial. The time-estimation feedback was only performance-based or in combination with a gain or loss of money. The no-gamble trials were indicated in advance by a specific visual cue (cubes instead of dice), and were employed to potentially prevent participants using a fixed strategy, e.g. always or never gambling, and to enhance engagement in the gamble trials. These trials were not included in the analysis, since they did not contain a gamble. Time–estimation performance on these trials did however affect the experimental balance, in case they would receive money.

In total, participants played on average 140 trials (approximately 12.5% "no-gamble" trials). The design contained a nested structure. 75% of the trials were experimental gamble trials (M, P, MP), that each contained approximately 50% positive and 50% negative feedback. Following each set of these positive and negative feedback, 1/3 of the trials had a negative EV gamble, 1/3 a zero EV gamble, and 1/3 a positive EV gamble, all randomly presented. Furthermore, 12.5% of the total trials were "control" trials that did not contain feedback, but contained the same distribution of the EV gambles. Each trial in the game varied between 9-13 seconds. The task was presented in Presentation® software (Version 14, www.neurobs.com).

Analysis

In order to assess the degree of risk-taking following positive and negative feedback contexts respectively, we assessed the number of gambles played/passed as a binomial dependent measure. We had three within-subject factors: 'context type' (three levels: Monetary (M), Performance (P), Combined (MP)), 'feedback context' (two levels: Positive, Negative), and 'gamble type' (three levels: positive EV, zero EV, negative EV). The Control trials did not have positive or negative feedback and were used to assess a baseline risk attitude, and were not entered into the main model. All behavioural statistics were computed using the R statistical package (R Development Core Team, R version 3.1.2 (Pumpkin Helmet), 2014). A generalized linear mixed effect model was performed, to avoid aggregating the data and due to the data being slightly unbalanced. For this, we used the *mixed* function of the package (afex, v.0.12-135) for Analysis of Factorial Experiments (Singmann, 2014), running on lme4 (v.1.1-7) (Bates, Maechler, Bolker & Walker, 2014). The model contained the three within-participant factors as fixed effects to predict participant's decisions to play or pass on a 50-50 mixed gamble (binary variable). To account for the repeated-measures and nested nature of the data, in the model we included random adjustments to the fixed intercept ("random intercept") for participant, including within-unit random slopes for context type, feedback context, gamble type, and an interaction term between feedback and gamble type within participant, allowing random correlations among random effects (e.g. Baayen, Davidson, & Bates, 2008; Barr, 2013; Barr, Levy, Scheepers & Tily, 2013). P values were determined using Likelihood Ratio Tests as implemented in the *mixed*() function (Singmann, 2014), and for all post-hoc pairwise multiple comparisons we used the general linear hypothesis test (*glht*) function of the multcomp package (v.1.3-8), suitable for generalized linear mixed effects models (Bretz, Hothorn & Westfall, 2008). Reported means are the least-squares means and confidence intervals (CI) are set at 95%, obtained using the *lsmeans* function of the lsmeans package (v.2.13) (Lenth, 2014).

Results

Gambling behaviour following different types of positive and negative feedback

Our main question of interest was to examine individuals' inconsistent risk preferences to gain and loss contexts by different types of feedback; monetary reward and punishment (M), performance success and failure (P), and performance success and failure in combination with a monetary reward and punishment (MP). Supporting previous findings (Tversky & Kahneman, 1979; Kahneman & Tversky, 1992; Weber & Camerer, 1998; Losecaat Vermeer et al., 2014), we find that participants' risk preferences were in general sensitive to positive and negative contexts (χ^2 (1)=16.91, p < .001). Participants took more risks after previously experiencing negatively-valenced feedback as compared to previously experiencing positively-valenced feedback, irrespective of the prior context (M_{negative} = 0.396, *CI* =[0.264, 0.546], M_{positive} = 0.224, *CI* =[0.122, 0.376]).

In terms of our primary question of interest, context type (M, P, MP) significantly influenced participant's risky behaviour following reward/ punishments (χ^2 (2)=28.62, p < .001). Experiencing incidental monetary gains and losses shifts subsequent risk preferences most strongly; $M_{\text{M loss}}$ = 0.471, *CI* =[0.332, 0.614], $M_{\text{M gain}}$ = 0.192, *CI* =[0.103, 0.327], z = 8.998, p <.001), experiencing performance-based monetary gains and losses also caused a significant shift in risk preferences, $M_{\text{MP loss}}$ = 0.366, *CI* =[0.232, 0.525], and $M_{\text{MP gain}}$ = 0.209, *CI* =[0.109, 0.363], though significantly weaker than pure monetary gain/loss feedback *(*χ^2 (2)=6.31 p = .01*)*. However, risk-taking behaviour following performance-based success did not significantly differ to that following failure ($M_{\text{P failure}}$ = 0.355, *CI* =[0.222, 0.514], $M_{\text{P success}}$ = 0.280, *CI* =[0.152, 0.457], z = 2.160, p = 0.257) (Fig. 2). In the control trials participants gambled, on average, 30% (*CI* =[0.189, 0.440]).

Examining the data more closely, we find that participants take more risk after a 'pure' monetary loss than after experiencing a monetary loss based on performance failure (Loss: M – MP, z = 3.436, p = .008), and as compared to performance failure only (Loss: M – P, z = 3.804, p = .002). In the positive context we find the opposite pattern. Participants took more risk after receiving success performance-based feedback than after 'pure' monetary gain (Gain: P – M, z = 3.246, p = .015), but not more than success performance-based feedback in combination with a monetary gain (Gain: P – MP, z = 2.545, p = 0.111). There was no significant difference in risk-taking whether participants received a 'pure' monetary gain or whether participants received a monetary gain in combination with success feedback (Gain: M - MP, z = -0.735, p = 0.978), and also not after receiving failure performance feedback, with or without a monetary punishment (Loss: MP – P, z = 0.320, p = 1.0). Overall participants did not take different proportion of risk following the different types of context (M_{MP} = 0.281, CI =[0.165, 0.435] M_{M} = 0.315, CI =[0.198, 0.461] M_{P} = 0.316, CI =[0.189, 0.478], χ^2 (2)= 2.48, p = 0.289).

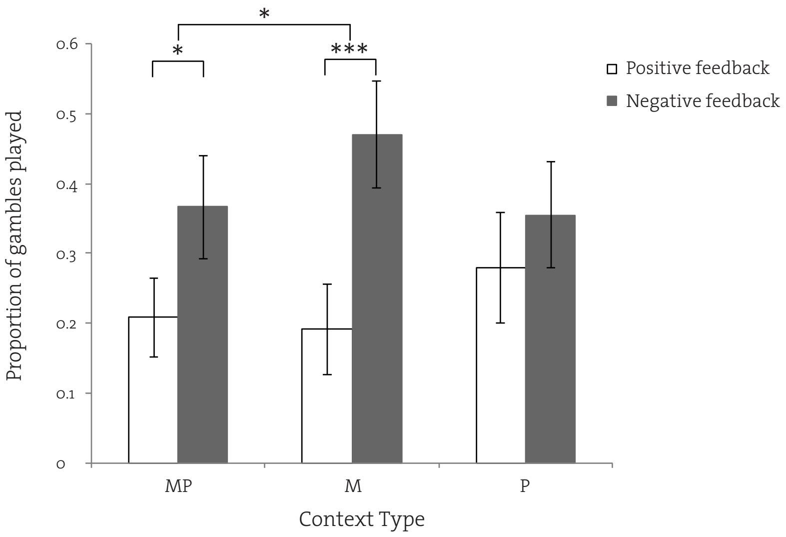

Fig. 2 Estimated marginal means of proportion gambles played following different types of positive and negative feedback contexts. MP = performance feedback including monetary reward/punishment, M = monetary gain/loss, P = performance success/failure. * p <.05, *** p <.001

Participants were sensitive to the expected values of the gambles, with the greatest willingness to play the positive EV gamble and the lowest willingness to play the negative EV gamble (M_{+EV} = 0.768, CI =[0.581, 0.888], M_{0EV} = 0.295, CI =[0.161, 0.478], M_{-EV} = 0.056, CI =[0.029, 0.107], χ^2 (2) = 44.50, p < .001). The expected value of the gamble also affected risk preferences differently following gains and losses (Feedback context x EV gamble: χ^2 (2) = 14.40, p = .001). For all expected values, participants gambled more following a loss compared to a gain. The type of context did not affect risk preferences for gambles with different expected values (χ^2 (2) = 2.45, p = .654).

Discussion

In the current study, we investigated whether context-dependent shifts in financial risk preferences are driven purely by the delivery of monetary gains/losses, or are rather due to performance-based success/failure, independent of monetary gains/losses. To examine this, we directly compared performance and monetary contexts prior to, and independent of, identical mixed gambles. Firstly, we replicated the framing behaviour for performance-based monetary gains and losses which we observed in our previous work (Losecaat Vermeer et al., 2014). Secondly, incidental pure monetary gains/losses affected risk preferences in the same direction, as did performance-based monetary gains and losses. Thirdly, we found that performance success and failure, independent of monetary gains/losses, did not differentially affect individuals risk preferences for subsequent gambles. In the fourth place, we found that incidental monetary gains and losses caused the largest shift in risk preferences, significantly more so than after performance-based monetary gains and losses. Finally, for all context types, people were equally sensitive to the expected values of the gambles, playing the highest expected value gambles more than the zero and negative expected value gambles. Moreover, the typical framing effect was observed for all gambles.

The finding that risk preferences are susceptible to prior positive and negative contexts, though only when these preceding contexts involve monetary gains and losses, is consistent with previous research (Barkan & Busemeyer, 2003; Xue et al., 2011), and can potentially be attributed to loss aversion (Kahneman & Tversky, 1979). Loss aversion, the finding that losses loom larger than equivalent gains, can lead us to pass on a mixed gamble which contains the possibility of losing money. However, in a situation in which we have already just lost money, either randomly or due to poor performance, a mixed gamble that offers a chance to redeem this loss becomes more preferred. Together, one possible explanatory process to the observed findings of the typical shift in risk preferences for mixed gambles following unrelated monetary reward/punishments, either randomly rewarded or based on performance, is our innate tendency to avoid losses.

A possible effect of experiencing performance success or performance failure feedback could be a difference in mood (Henkel & Hinsz, 2004) that might in turn influence preferences for risk. Prior studies examining the effect of positive and negative mood on risk preferences, found that incidental positive mood influenced subsequent preferences for high risk gambles (Knutson et al., 2008), and enhanced framing effects (Stanton & Reeck, 2014). In the current study, we did not find a difference in risk preferences following pure performance success/failure, independent of monetary gains and losses. A potential mood effect seems unlikely to underlie the observed effects in risk. Moreover, performance success and failure feedback was based on participants' actual performance, which is different to experiencing incidental monetary gains and losses used in this study, or incidental affective stimuli in other studies (Knutson et al., 2008; Stanton 2014). Performance as such, could be too unrelated to the subsequent gamble decision in order to be integrated into the valuation of subsequent choice. This is consistent with the compatibility effect (Slovic, Griffin & Tversky, 2002), which suggests that outcomes that are compatible with the output of choice are given more weight. Monetary gains and losses are compatible with the outcome of mixed gambles, whereas performance success and failure are less so, leading to a stronger impact on behaviour for the former. Nevertheless, when comparing the different context types for positive and negative valence separately, we find that success feedback does indeed increase subsequent risk-taking, but only compared to pure monetary gains. It should be noted, during the Play trials, participants did not know in advance in which trials they would receive only performance feedback, and in which trials they would receive performance feedback with a monetary reward or punishment. These different context types were randomized across Play trials. The lack in behavioural difference for risk following performance-based feedback could have resulted in this possible confound. That is, compared to receiving a monetary reward when successful in performance, when solely receiving successful feedback, a participant might feel disappointed due to not receiving a monetary bonus in addition, and vice versa for negative feedback. As a result, positive and negative performance feedback might cancel each other out by the lack of monetary feedback; therefore do not influence risk preferences differently.

The finding that behavioural framing effects for incidental monetary gains and losses were stronger relative to performance-based monetary gains and losses, suggest that these framing effects are primarily driven by the receipt of monetary outcomes, and not, or less so, by success and failure, as shown by pure performance-based contexts. Additional feedback about performance success or failure may reduce loss aversion. It is likely that receiving a 'random' monetary loss may feel less acceptable and unfair, due to not having any control over the outcome. Receiving an incidental monetary loss may therefore enhance the willingness to gamble this money back, which the current data supports. Conversely, incurring a loss based on erroneous performance might be more justified, and therefore might result in less strong framing effects. For both pure monetary gains as well as performance-based monetary gains, we found a similar degree of risk aversion for mixed gambles.

The differential effects we found for pure performance-based success/failure, and performance-based success/failure in combination with monetary gains/ losses, have also been observed with functional neuroimaging data. Monetary reward and punishments exhibited more enhanced activity in overlapping brain

3

regions compared to pure performance-based success and failure (Daniel & Pollmann, 2010; Lutz, Pedroni, Nadig, Luechinger & Jäncke, 2012; Aron et al., 2004; Tricomi, Delgado, McCandliss, McClelland & Fiez, 2006). These areas have also been associated with anticipation of reward and financial risk-taking (Knutson et al 2001; Delgado et al., 2003, 2004; Kuhnen & Knutson, 2005). The stronger response in the reward and punishment-related network in the brain to monetary feedback relative to performance-based feedback supports our finding that monetary feedback influences subsequent choice more strongly than monetary feedback confounded with performance-based feedback.

The current findings indicate that participants' risk preferences in case of monetary gambles are very susceptible to monetary contexts, and that this effect does not extend easily to non-monetary contexts, or most likely non-compatible contexts. The observed context-specificity seems to reflect a compatibility effect (Slovic et al., 2002), along the lines that preceding monetary gain/loss outcomes (than success or failure by itself) are easier to integrate into the choice process to play/pass a gamble consisting of monetary outcomes. Hence, different positively or negatively valenced contexts do not affect risk preferences in a consistent way. Future studies could provide more insight into how these different types may affect our valuation of risky choice, by examining the underlying psychological and neural differences mediated by different reward and punishment contexts. Furthermore, examining whether contextual effects of different context types exist for risk choices containing non-monetary outcomes, e.g. health-related decisions, would be interesting to gain a better view of cross-context effects on risk.

To summarize, in the current study we showed that risky shifts following a prior positive and negative feedback seem to be differently affected by contexts that are based on money or on individuals' performance. The risky shift (i.e. framing effect) is primarily driven by monetary gains and losses and not due to success or failure in an unrelated task. In other words, simply seeing the results of a lottery in which participants won or lost preceding a monetary mixed gamble, without performing any task, enhanced the current framing effect. On the contrary, when participants were just informed whether they were successful or unsuccessful in the estimation task, risk preferences for mixed gambles became consistent, and thus, framing disappeared. These results highlight the strong specific context-dependency of risk preferences and choices, and suggest that positive or negative valence or mood do not influence this, but that a process explaining the observed inconsistent risk preferences following gain and loss outcomes is our aversion to losses.

4

Third-party decision-making under risk as a function of prior gains and losses

Abstract

Living in a social environment entails that we not only make choices for ourselves, but also on behalf of others. Here, we explored how third-party decision-making can alter risk preferences as a function of prior gain and loss framing contexts, and furthermore how the level of responsibility for third-party choices impact these effects. Participants played a series of trials where they could either win or lose money depending on their performance on a simple reaction time task. Immediately following the respective gain or loss, the participant decided to either play or pass on a 50/50 mixed gamble that could either double or eliminate their gain (after a prior win) or redeem or double their loss (after a prior loss). If they chose not to play this gamble, they retained the initial gain or loss. Participants played the task either for themselves ("*Self*" Condition) or for another, anonymous, participant ("*Other*" Condition). Additionally, we manipulated between subjects the level of responsibility for choices in the Other condition, resulting in an *Other-High* and *Other-Low responsibility* group. Participants made more risky choices after incurring a loss as compared to a gain. While this shift in risk preferences occurred for both Self and Other choices, it was significantly *smaller* for Other choices, with the difference decreasing as responsibility for the decisions decreased. Reduced engagement of affective processes when deciding for others, particularly when responsibility is low, may underlie the increased consistency in risk preferences following gains and losses.

Based on: Losecaat Vermeer, A. B., Boksem, M. A. S. & Sanfey, A. G. (*under review*) Third-party decision-making under risk as a function of prior gains and losses.

Introduction

Living in a social environment entails that we not only make choices for ourselves, but also often on behalf of others. For example, parents make many decisions for their children, and sometimes children later choose on behalf of their parents, financial advisors make investment choices for their clients, and research supervisors may decide as to the direction of inquiry that their students undertake. Deciding for a third-party can also occur in a broader context, such as when a CEO makes choices directly impacting employees, or a politician deciding on public policy affecting millions. Despite this apparent ubiquity of situations in which the decision-makers themselves may not be directly affected by the outcome of their choice, there is a surprising dearth of research examining differences between choices made for oneself and choices made for another.

The majority of research in the area of third-party decision-making has been conducted in the context of medical choices, with the canonical example of a medical doctor deciding between potential treatments for a patient when these options differ in risk and efficacy. In such situations, research demonstrates that doctors tend to take less risk when deciding on behalf of a patient considering a risky or a safer treatment, as compared to when they make the same decision for themselves (Garcia-Retamaro & Galesic, 2012). This suggests that risk preferences may be impacted by the degree to which one is directly affected by the decision outcome.

Understanding how people make decisions on behalf of a third party, particularly when these decisions entail some degree of risk, is a question of substantial importance for society. However, while interest in third-party decisions under risk is growing, there are still many inconsistencies in the literature. For instance, studies from a variety of fields have found evidence for *increased* risk-taking behaviour when deciding on behalf of another person. This increased risk-taking for a third-party has been observed for making choices for friends about romantic relationships (Beisswanger et al., 2003; Wray & Stone, 2005), and for monetary choices involving risk, both real and hypothetical (Agranov & Bisin, 2011; Chakravarty et al., 2011; Hsee & Weber, 1997). Conversely, some studies have observed *decreased* risk-taking when deciding for another. For example, in an investment lottery game participants took less risk when playing on behalf of an anonymous other participant as compared to participants playing for themselves (Eriksen & Kvaloy, 2010), a result also shown when deciding on behalf of a group (Reynolds, Joseph & Sherwood, 2009). Further studies have found no difference in risk-taking between self and other (Stone, Yates & Caruthers, 2002). Given the importance of these decisions in real-life, these mixed findings regarding self-other discrepancies in risk-taking behaviour suggest that a better understanding of the nature of self-other differences for risk is required.

A substantial amount of work has shown that risk perception and preferences are domain-specific (Kahneman & Tversky, 1979; Weber, Blais & Betz, 2002), and so a possible explanation for the inconsistent findings is that different contexts (i.e. social, non-social, hypothetical, and real) may induce different psychological mechanisms. For example, foundational work from Kahneman and Tversky (1979, 1981) has shown that when a decision problem is described in a positive frame (i.e. focusing on potential gains), people tend to be risk averse, that is, they shy away from riskier options. However, when the same decision problem is presented in a negative frame (i.e. focusing on potential losses), people tend to relatively favour the risky option. Previous experience has also been shown to affect an individual's preference for choosing a risky or safe option, with various studies examining how prior outcomes can change preferences for risky choice (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992; Weber & Camerer, 1998; Barkan & Busemeyer, 1999; Xue, Lu, Levin & Bechara, 2011). In a recent study (Losecaat Vermeer, Boksem & Sanfey, 2014; Chapter 2) we examined how prior gains and losses, unrelated to the task at hand, can change our preference for risky choice. Participants who had experienced a prior monetary loss subsequently chose to play a mixed 50-50 "double-or-quits" gamble significantly more often than playing an identical gamble after experiencing a prior gain. Importantly, this effect was observed within-subjects, that is, participants' individual preferences for risk shifted as a function of prior outcomes. These studies illustrate the importance of taking into account the decision context (e.g. in this case the presence of prior outcomes) in understanding risk-taking behaviour. An interesting, and still open, question however is whether this pattern of inconsistent choice as a function of prior gains and losses is affected by the degree to which the decision-maker is directly influenced by the outcome (i.e. deciding for oneself or another). In the present study we attempt to better specify the conditions under which inconsistency in risk-taking may be influenced by deciding either for oneself, or on behalf of a third-party.

One important factor that may account for the aforementioned self-other differences in risky choice is the extent to which the decision-maker is responsible for the outcome of his or her actions (Beisswanger et al., 2003; Harkness, Debono & Borgida, 1985). One example is bankers' excessive risk behaviour leading up to the financial crisis in 2008 - to some degree this has been attributed to a lack of responsibility for the outcomes of ill-advised investment strategies. Studies have shown that when a decision-maker is responsible for other individuals, or even an entire group, in addition to themselves, less risky strategies are often chosen (Charness & Jackson, 2009; Reynolds et al., 2009). Other studies have observed that self-other differences were a result of the opportunity to avoid taking responsibility by choosing an outcome determined by chance rather than choosing the outcome, indicating here that participants responsibility aversion led to self-other differences (Leonhardt, Keller & Pechmann, 2011; Beisswanger et al., 2003). In addition, being evaluated or having to justify one's decisions to the recipient ("accountability", Lerner & Tetlock, 1999) increased risk-taking for mixed gambles when compared to purely being held responsible for the payoffs (i.e. when only the decision-makers' ID was disclosed to the recipient) (Pahlke, Strasser & Vieider, 2012). In the latter study, decisions affected payoffs equally for the decision-maker and recipient. The aforementioned studies suggest that self-other differences in risk-taking could be a result of differences in responsibility, however, in which direction, and whether differences in responsibility can impact one's susceptibility to a decision context in shaping risk preferences is still unclear.

In this study, our aim is to examine whether the extent to which someone is held responsible for deciding on behalf of a third-party affects self-other differences in risk preferences, in particular those risky choices taken immediately following gains and losses. To induce gain and loss contexts, participants played multiple trials in which they could either win or lose money depending on their performance on a time-estimation task. Immediately thereafter, the participant decided if they wanted to play a 50/50 mixed gain/loss gamble that could either redeem or double their loss (after an initial loss), or double or eliminate their gain (after an initial gain). If the participant decided not to play this gamble (i.e. pass), they would simply retain the initial gain or loss. In order to induce actual gain and loss contexts, participants played multiple trials. The critical manipulation was whether the participant played the task with the beneficiary as either themselves ("*Self*") or another, anonymous, participant ("*Other*"). In addition, when choosing on behalf of the other, we manipulated the degree of information being disclosed about the decision-makers' behaviour to the recipient. Participants were instructed that the recipient would evaluate this information and determine a potential bonus payment for the participant. This additional manipulation therefore allowed us to answer the question of whether the *level* of responsibility in the process of choosing for another changes preference for risk, with two different conditions examined: 1) the participants' full choice history as well as the final monetary outcome of the task would be revealed to the recipient ("*high responsibility*"), and 2) only the final monetary outcome of the decisions would be revealed to the recipient ("*low responsibility*").

Materials and Methods

Participants

118 undergraduate students participated in the study. All gave written informed consent and received research credits for participation. Participants could earn a monetary bonus depending on either their own choices (Self condition, $N = 41$) or the choices of another player (Other condition, $N = 77$), with this bonus being €0, €5, or €10. Experimental exclusion criteria were a self-reported history of psychiatric disorders, regular use of marijuana, or use of psychotropic drugs. Three participants in total were excluded. One male was excluded because of reported regular drug use, and the two remaining males were excluded to enable an analysis of a homogenous sample in terms of gender. Data is therefore reported from 115 participants (all female, $M = 19.76$ years, $SD = 1.64$). The study was approved by the local ethics committee.

Design

We used an existing paradigm (Boksem, Kostermans & De Cremer, 2011; Losecaat Vermeer et al., 2014) in order to study risk-taking behaviour in the context of prior gains and losses. Each trial began with a simple time-estimation task in which participants either won or lost money (€1.20) depending on their performance. The purpose of this task was to induce either a gain or a loss context on that trial. Directly after the respective gain or loss feedback from the time-estimation task, participants received a mixed (50/50 chance, gain/loss) gamble, which they could decide to either play or pass (see Figure 1). If they decided to pass on the gamble they would simply retain their gain or loss from the preceding time-estimation task, with this amount added to (or subtracted from) their total monetary balance. Alternately, if they decided to play the gamble, the gamble was then resolved and the corresponding win or loss amount was added to their total balance. As compared to the 'pass' option (i.e. choosing to simply retain the €1.20 gain or loss), each mixed gamble yielded either a positive expected value ('+ EV'), an expected value of zero ('0 EV'), or a negative expected value ('- EV'), with these values reached by varying the gain or loss outcome between €1.00, €1.20, and €1.40 respectively. These three different gamble types were created to assess whether participants were sensitive to the expected value of the gamble.

The critical manipulation here was that participants either played the task for themselves (*Self* condition), in which case their total earnings would then be paid out to directly to them, or they played for another participant (*Other* condition), whereby a randomly selected, anonymous, experimental participant would receive the total earnings. It was made clear to participants in the *Other* condition that another experimental participant would also play for them, who would be determined randomly at the end of the experiment, when all participants had participated. Moreover, participants were told at the beginning of the task that depending on their experimental condition they would be compensated based on their own behaviour, or of another participant, when the study was completed.

In addition, we manipulated the degree of responsibility within the *Other* condition to examine whether responsibility may also have an effect on risk-taking. Half of the participants (N = 39) in the *Other* condition were told that the recipient of the final balance would rate his or her satisfaction with the monetary outcome, which we refer to as the Other-Low responsibility (*Other-L*) group. The other half of the participants (N = 38) from the *Other* group were informed that both the final balance itself *as well as* the actual behavioural performance during the task (i.e. the sequence of choices they made) would be rated by the other recipient, which we refer to as Other-High responsibility (*Other-H*) group. The distribution of participants for the two *Other* conditions was done pseudo-randomly. An additional small bonus could be earned if the ratings of the recipient were positive.

Procedure

Participants first performed two practice sessions of 5 minutes. In the first session participants practiced the time-estimation trials. Here, participants were required to estimate the duration of one second. After a cue on the screen changed in colour, they were instructed to wait exactly one second and then press a response button, with their precise response times recorded. We used a staircase procedure in which we adjusted the interval until we reached 50% accuracy for each participant, to determine the initial allowable response time-window per participant in the experiment, which in turn was used to give feedback on whether their response on the time-estimation task was either correct or incorrect. The second practice session gave participants the opportunity to practice the gambling task itself. After these practice sessions, the experiment began. It lasted for approximately 60 minutes, with a short break halfway.

Before the task started, participants were instructed that their goal was to win as much money as possible, either for themselves (*Self* condition) or for another random participant (*Other* condition). A small icon at remained at the top of the screen throughout the task to remind the participant of the experimental condition (see Figure 1). They were told that their final balance would actually be paid out to the respective recipient (up to a maximum of €10), in addition to the participation credits they would receive irrespective of condition or performance. In case of the two *Other* conditions, the total end balance that the participant earned during the experiment was randomly assigned to one of the other anonymous participants at the end of the experiment. At the same time, earnings

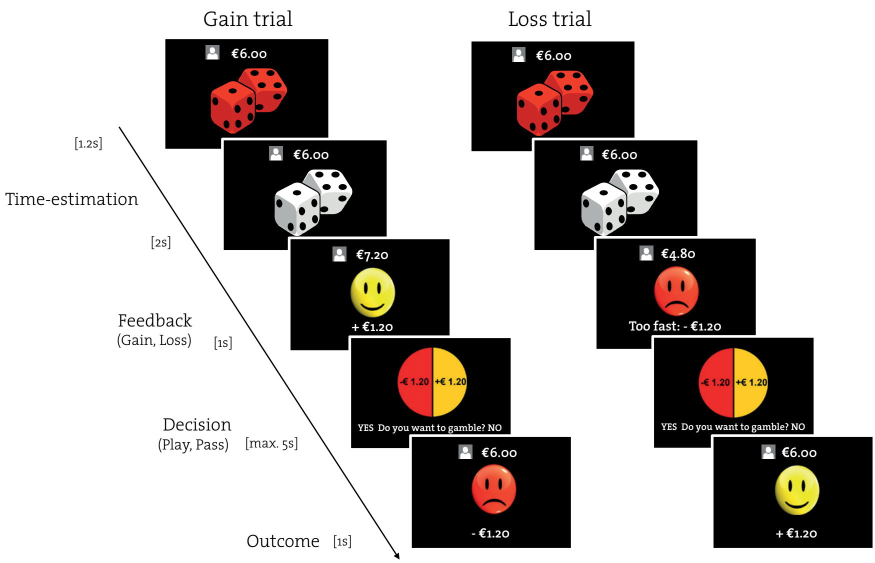

Fig. 1 Task design. The structure of a single gain and single loss trial is presented. In this example the *Other* condition is shown. Each picture represents a screen in the experiment. The trial started with a time-estimation task, where participants were required to press a button exactly 1 s after the dice colour changed to white. Feedback on performance was shown as a monetary gain of €1.20 if correct, or a loss of €1.20 if incorrect. Following this feedback, participants had the opportunity to choose a mixed gamble with a 50/50 chance to either gain or lose money. If participants decided to gamble, the gamble was played and the outcome then presented. Average duration of a trial is 9-13 s. The task was the same for the *Self* condition with the exception of the icon displayed at the top of the screen.

of an anonymous other participant was also randomly assigned to the decision-maker in the *Other* condition. The bonus payment in the *Other-Low responsibility* condition was determined by a positive satisfaction rate (between 5-7 out of a 1-7 satisfaction Likert scale) of the receiver that was based on the total end outcome, whereas the bonus payment in the *Other-High responsibility* condition was determined by a positive satisfaction rate (between 5-7 out of a 1-7 satisfaction Likert scale) of the receiver that was based on the entire choice behaviour during the experiment in addition to the total end outcome. At the end of the experiment, participants gave their ratings online (Qualtrics software, 2013). All participants had to return to receive their payments, in both conditions. The only difference is that participants in the *Self*-condition already knew what they had earned at the end of the task.

Task and Stimuli

At the start of each trial, participants saw a red visual cue that changed in colour to white after 1200 ms (Figure 1). Participants were then required to press the response button exactly 1 second after this colour change. Responses to this time-estimation task were considered correct when they were within an allowable time-interval. For correct responses, participants gained €1.20. Participants lost €1.20 if their response was not within this time-interval, i.e. either too fast or too slow.

The allowable response-interval was initially calculated based on their performance in the practice run and then covertly adjusted throughout the task as a function of the variance in response time of the participant, in order to ensure an approximately equal number of gains and losses on this task. If participants responded within the allowable response-interval, this interval was subsequently shortened by 50 ms; if they responded either too quickly or too slowly, the interval was then lengthened by 50 ms. Importantly, although the relative number of gains and losses was manipulated, the feedback itself, and the associated gains and losses, was contingent upon participants' performance (see Boksem et al., 2011).

Participants were given the opportunity to play a gamble on 75% of trials. They were forewarned on each trial by the presence of a specific visual cue, namely a pair of dice. On these 'gamble' trials, after receiving the feedback from the time estimation task (gain or loss), participants could choose to either play or pass on a mixed (50/50 chance, gain/loss) gamble (within 5 s.). Playing the gamble led to two possible outcomes: 1) A win outcome which added between €1.00, €1.20 or €1.40 to their overall experimental balance, or 2) a loss outcome which subtracted between €1.00, €1.20 or €1.40 from this balance. Alternatively, the participant could decide to pass on the gamble, thereby keeping the earlier gain or loss (i.e. +/- €1.20) from the time-estimation task. The gamble outcomes were independent from the performance on the time-estimation task.

In the remaining 25% of trials, participants were not presented with a gamble after receiving feedback on the time-estimation trial. These "no-gamble option" trials, indicated in advance by a specific visual cue (cubes instead of dice), were employed to potentially prevent participants using a fixed strategy, e.g. always or never gambling, and to enhance engagement in the gamble trials. Time–estimation performance on these trials did however affect the monetary balance. All gamble outcomes (both gains and losses) were reflected immediately in the total running balance displayed for each participant. This balance was shown on the screen at all times. Participants were informed that this would be the balance paid out (if positive) as a bonus at the end of the experiment. Furthermore, the running balance might also influence individual risk preferences, in addition to the expected effect of immediate gains and losses incurred on that particular trial. To control for this, during the task and unbeknownst to the participants, we manipulated the overall running balance to create phases of "neutral" (total balance range of €-5 to €5), "negative" (range €-5 to €-17), and "positive" experimental balances (range €5 to €17). A similar staircase procedure for the time-estimation interval was used in order to transition through these running balances. To transition up to a positive balance, the allowable response-interval was shortened by 10 ms after a correct response, and lengthened by 100 ms after an incorrect response (i.e. too quickly or too slowly). The same adjustment to the window was realized to transition down to a negative balance, in the opposite direction. The transition trials consisted both of gamble-trials (33%) and no-gamble option trials (67%), and were not used as experimental trials for analysis. Only the trials during the three balance phases were included in the analyses (see Boksem, Kostermans, Milivojevic & De Cremer, 2012). The order of these three phases of running balance was counterbalanced.

In short, every action the participant performed, their time-estimation performance and decision to play or not to play the gamble affected their total running balance (*Self*-condition), or the others' total running balance (*Other*-condition). With this manipulation we could test whether any direct (Self group) and indirect (Other group) wealth effects would influence risk consistency. Moreover, this made the task more engaging and realistic, as compared to other studies that use hypothetical scenarios or chose a random trial for payment.

In total, participants played on average 240 experimental trials (including approximately 60 "no-gamble option" trials). The factorial design included on average a total of 90 gain and 90 loss trials, these gain/loss outcomes were presented contingently on the participants' behaviour. Within each set of these 90 trials, we had 30 negative EV, 30 neutral EV, 30 positive EV gambles randomly presented. Within the total 180 experimental trials, 60 occurred with a positive running balance, 60 with a neutral running balance, and 60 with a negative running balance, counterbalanced across participant. The large amount of trials was employed to ensure adequate power to examine both play and pass decisions, since we cannot control participants' choice behaviour. Each trial varied in duration between 9-13 s., resulting in estimated task duration of 60 min. The task was presented in Presentation® software (Neurobehavioural Systems, Inc., Version 14).

Behavioural analysis

In order to assess the degree of risk-taking following gains and losses respectively, we assessed the number of gambles played/passed as a binomial dependent measure. We had three within-subject factors: 'running balance' (three levels:

Positive, Neutral, Negative), 'feedback context' (two levels: Loss, Gain), and 'gamble type' (three levels: positive EV, equal EV, negative EV). The between-participants factor was the recipient of the final outcome and the degree of personal involvement (three levels: *Self* (N = 38), *Other-High responsibility* (Other-H; N = 38), *Other-Low responsibility* (Other-L; N = 39)). All behavioural statistics were computed using the R statistical package (R Development Core Team, R version 2.15.3 (Security Blanket), 2008). A generalized linear mixed effect model was performed, using the *mixed* function of the package (afex, v.06-82) for Analysis of Factorial Experiments (Singmann, 2013), running with lme4 package (version 1.0-4) in R (Bates, 2010). The model contained the three within-participant factors and recipient as factors to predict participant's decisions to play or pass on a 50-50 mixed gamble (binary variable). To account for the repeated-measures of the data (each running balance contained the fixed effect 'feedback' and 'gamble type'), two random adjustments to the fixed intercept ("random intercepts") were included in the model: one random intercept coding for participant, and one random intercept coding for participant crossed with running balance (e.g. Baayen, Davidson, & Bates, 2008). Within-unit random slopes were not included, due to non-convergence of the model. P values were determined using Likelihood Ratio Tests as implemented in the *mixed*() function (Singmann, 2013), and for all post-hoc pairwise multiple comparisons we used the general linear hypothesis test (*glht*) function of the multcomp package, suitable for generalized linear mixed effects models (Bretz, Hothorn & Westfall, 2008). Reported means are least-squares means and confidence intervals (CI) are set at 95%, obtained using the *lsmeans* function of the lsmeans package (v.1.10) (Lenth, 2013).

Results

As expected, and supporting previous findings (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992; Weber & Camerer, 1998) participants were more likely to accept a gamble when they previously experienced a loss as compared to a gain (M_{Loss} = 0.571, CI = [0.513, 0.627], M_{Gain} = 0.418, CI = [0.362, 0.476]; χ^2 (1) = 339.23, p < .001). Importantly, this feedback effect interacted significantly with the between-participant factor of recipient type (*Self, Other-H*, and *Other-L*; χ^2 (2) = 44.35, p < .001; see Figure 2), such that with an increase in the level of responsibility there was a larger difference in risk-taking for losses versus gains. Examining the means, this interaction appears largely driven by the differences in decisions after gains, even though pairwise comparisons of the gains were not significant (p = 0.253). For participants playing for another recipient, for both the high and low responsibility groups, the difference in risk-taking as a function of the

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feedback context was significantly decreased as compared to participants playing for themselves (M_{Loss} = 0.576, CI = [0.504, 0.644], M_{Gain} = 0.459, CI = [0.389, 0.531] for *Other*; M_{Loss} = 0.563, CI = [0.461, 0.660], M_{Gain} = 0.344, CI = [0.258, 0.442], for *Self*; Feedback (loss, gain) by Recipient (Self, Other): χ^2 (1) = 35.39, p < .001). Specifically, responsibility impacted differences in risk-taking; participants in the low responsibility group were significantly less susceptible to the feedback context (i.e. a smaller difference between risk-taking following gains and losses) as compared to participants of the high responsibility group (For *Other-H*: $M_{Loss\text{-}Gain}$ = 0.148; for *Other-L*: $M_{Loss\text{-}Gain}$ = 0.09; χ^2 (1) = 8.96, p = .003).

The results show that when deciding for oneself, participants are more susceptible to the context in which a decision is made than when participants make ostensibly the same decisions for another participant. When the participant knows that the recipient will be explicitly rating the participant's decisions (*Other-H*), choices are more similar to those made for oneself than to those made when the decisions would not be rated (*Other-L*). Overall, across both gain and loss contexts, there was no significant difference in risk-taking between the groups (*Self*: M = 0.451, CI = [0.354, 0.552]; *Other-L*: M = 0.528, CI = [0.429, 0.625]; *Other-H*: M = 0.504, CI = [0.404, 0.604]; χ^2 (2) = 1.17, p = 0.557).

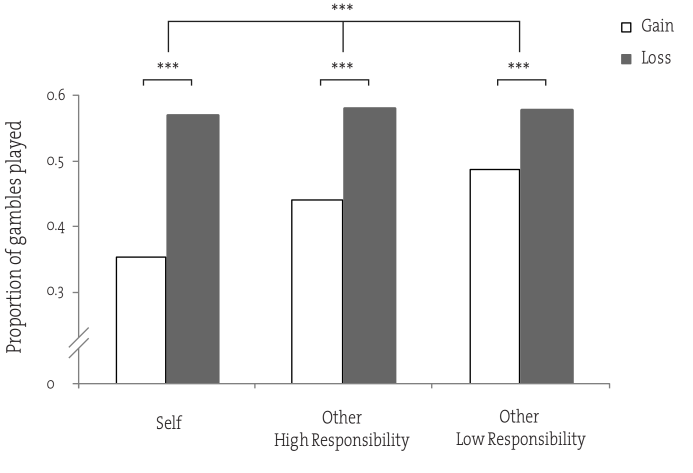

Fig. 2 Risk-taking choices following gains and losses per group; playing for oneself (*Self*), playing for a third-party in which both the participants' choice behaviour and total outcome was disclosed to the other person (*Other - High responsibility*), playing for a third-party in which only the participants' total outcome of the game was disclosed to the other person (*Other - Low responsibility*). *** p < .001.

Furthermore, because of the length of the task due to the experimental design, we tested for possible time effects on risk-taking, as it is possible that performance changed over time. To test this we distributed trials over 3 timebins of 60 gamble trials each. The willingness to gamble across groups significantly decreased over time ($M_{Timebin(1)} = 0.530$, $CI = [0.465, 0.594]$; $M_{Timebin(2)} = 0.491$, $CI = [0.426, 0.555]$; $M_{Timebin(3)} = 0.464$, $CI = [0.400, 0.529]$; χ^2 (2) = 6.82, $p = 0.033$), however, between groups there was no difference in risk-taking over time (group by time: χ^2 (4) = 1.95, $p = 0.746$).

Participants were sensitive to the expected values of the gambles, with a higher likelihood to play the positive EV gamble and a lower to play the negative EV gamble ($M_{+EV} = 0.722$, $CI = [0.672, 0.767]$; $M_{0EV} = 0.505$, $CI = [0.447, 0.564]$; $M_{-EV} = 0.260$, $CI = [0.217, 0.309]$; χ^2 (2) = 2363.29, $p < .001$). Moreover, this effect was also observed within all groups (*Other-H*: $M_{+EV} = 0.771$, $CI = [0.690, 0.836]$; $M_{0EV} = 0.543$, $CI = [0.441, 0.642]$; $M_{-EV} = 0.208$, $CI = [0.148, 0.284]$; for *Other-L:* $M_{+EV} = 0.725$, $CI = [0.637, 0.798]$; $M_{0EV} = 0.528$, $CI = [0.427, 0.627]$; $M_{-EV} = 0.322$, $CI = [0.240, 0.416]$; for *Self*: $M_{+EV} = 0.664$, $CI = [0.576, 0.750]$; $M_{0EV} = 0.446$, $CI = [0.347, 0.548]$; $M_{-EV} = 0.259$, $CI = [0.188, 0.346]$; EV gamble by recipient: χ^2 (4) = 90.22, $p < .001$).

The different phases of experimental running balance did not significantly interact with recipient group (across groups: $M_{\text{positive}} = 0.465$, $CI = [0.401, 0.530]$, $M_{\text{neutral}} = 0.500$, $CI = [0.435, 0.564]$, $M_{\text{negative}} = 0.519$, $CI = [0.454, 0.583]$; χ^2 (4) = 1.80, $p = 0.772$), but did significantly interact with feedback context (For loss-gains: $M_{\text{positive}} = 0.093$, $M_{\text{neutral}} = 0.180$, $M_{\text{negative}} = 0.184$) ($\chi^2$ (2) = 23.72, $p < .001$). When playing with a positive overall balance, participants were less, though still significantly, susceptible to the loss-gain context, in comparison to playing with a neutral or negative balance (Negative: $z = 13.02$, $p < 0.001$; Neutral: $z = 12.55$, $p < 0.001$; Positive: $z = 6.55$, $p < 0.001$). Post-hoc comparisons revealed that participants were differently sensitive to the losses and not the gains. That is, participants gambled significantly less often after a loss with a positive running balance, as compared to with both neutral and negative running balances (For Loss only: $z_{\text{(positive - negative)}} = -3.64$, $p = 0.003$, $z_{\text{(positive - neutral)}} = -2.83$, $p = 0.045$, no significant difference between a negative and neutral balance.).

Discussion

In this study we examined the effects of making risky decisions for oneself versus for a third-party, in particular focusing on the degree to which risk preferences shifted following preceding monetary gains or losses. To investigate this, participants were assigned to choose either for themselves or for another, anonymous, person. Within the third-party condition, participants were further

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divided into two groups, one in which the third-party recipient was viewed both the actual set of choices (the decision history) as well as the overall outcome, and one in which the recipient only saw the final outcome. In each trial, the decision-maker first received a small monetary reward or punishment (the gain/loss frame) based on performance on a response-time task, and then chose to either play or pass on a risky “double-or-quits” gamble.

Replicating earlier work on preference shifts for risk (Losecaat Vermeer et al., 2014), when participants decided for themselves they were indeed sensitive to the prior gains and losses, choosing significantly more gambles when they had just incurred a small loss as compared to when they received a small gain. This demonstrates the reliable effect of a decision frame – we observe changes in individual risk preferences for identical sets of gambles as a function of a small preceding monetary gain or loss.

The primary goal of the present study was to examine how choosing for either oneself or another, anonymous, participant could alter these preference shifts. Our findings indicated that when deciding for others, participants were significantly less susceptible to this gain/loss context, demonstrated statistically by a significant interaction effect between the gain/loss feedback and the recipient type. In other words, participants exhibited greater risk-taking after a loss then after a gain, with this difference larger when individuals were deciding for themselves as compared to for others. Additionally, people who were *least* responsible for their decisions, namely the group whose exact trial-by-trial decisions were *not* revealed, showed the smallest shift in risk preferences for gain and loss contexts. Overall then, when the level of responsibility was at its smallest, participants were most consistent in their risk preferences across gain and loss contexts, whereas when responsibility was maximal, when you choose for yourself, the impact of context on risk preferences is at its largest.

Diminishing sensitivity to prior gains and losses when deciding for a third-party is in line with research examining loss aversion for decisions involving choosing to play mixed gambles for others as compared to for oneself. Loss aversion, the tendency to overweight losses as compared to gains (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992), has been shown to be diminished when choosing on behalf of someone else (Mengarelli, Moretti, Faralla, Vindras & Siriguet, 2014; Polman, 2012). This behavioural tendency has been associated with the involvement of affective processes (Sokol-Hessner et al., 2009), with individual’s degree of loss aversion to correlate positively with the involvement of affective processes.

Functional neuroimaging work has shown that when observing preference shifts for choices framed as gains or losses (De Martino, Kumaran, Seymour & Dolan, 2006), or presented as mixed gambles (Tom, Fox, Trepel & Poldrack, 2007; De Martino, Camerer & Adolphs, 2010), or as mixed gambles followed by prior gains or losses (Losecaat Vermeer et al., 2014), brain regions involved in affect- and reward-related processes are more engaged (i.e. amygdala, striatum, and ventromedial prefrontal cortex) as compared to behaviour showing consistent risk preferences or the opposite direction of the typical shift in risk preferences. Moreover, decisions that were not influenced by this valence frame were related to greater engagement of regions involved in control and inhibition, i.e. anterior cingulate cortex and orbitofrontal cortex (De Martino et al., 2006). The neural and psychological findings on loss aversion and framing indicate that people exhibiting diminished sensitivity to context framing rely less on affective processes, and therefore potentially more on cognitive control processes, when making choices under risk.

These findings support the idea that a potential mechanism underlying the self-other differences in risk consistency for gain/loss contexts is one of reduced engagement of affective processes in evaluating the preceding gain and loss outcomes in deciding to take risk or not. In a similar vein, research in non-risk related decision-making has shown that deciding for a third-party attenuates emotional responses towards the context of the choice (i.e. unfair vs. fair offer, immediate vs. delayed rewards), which has in turn been related to reduced activity in reward and affect-related brain regions (Civai et al., 2010; Albrecht, Volz, Sutter, Laibson & von Cramon, 2011; Corradi-Dell'acqua, Civai, Rumiati & Fink, 2013). For example, one psychophysiological study showed that receiving unfair monetary offers on behalf of another player resulted in a reduced emotional response, whereas when the participant themselves was the recipient there was a large increase in the emotional response (Civai et al., 2010).

In our study, responsibility led to differences in the susceptibility to the gain/loss context on subsequent risky choice. Greater responsibility for the decisions increased the impact of gains and losses on participants' subsequent risk preferences, most evident when the participant themselves was the beneficiary of the choices, but also observed when the full decision history was shown to the third-party. One plausible explanation as to how responsibility affected risk preferences for gains and losses is that it enhanced the impact of choice outcomes. More specifically, the greater the responsibility on the decision-maker, the closer the outcomes will be to the self. The closer the outcomes are to the self, the greater their affective impact will be, and the stronger they will shift risk preferences. Responsibility is closely linked to self-referential emotions, such as the anticipation of guilt (Berndsen, van der Pligt, Doosje & Manstead, 2004; Chang, Smith, Dufwenberg & Sanfey, 2011) and regret (Camille, Coricelli, Sallet, Pradat-Diehl & Duhamel, 2004; Camille et al., 2010; Coricelli, Dolan & Sirigu, 2007) during decision processes. For instance, responsibility for negative outcomes increases regret, and in particular the aversion for regret and experience of regret elicits orbitofrontal and amygdala activity (Nicolle, Bach, Frith & Dolan, 2011), a response that reoccurs just before the choice, possibly guiding on 17th June stated is behaviour away from regrettable choices (Coricelli et al., 2007). This is also in line with studies showing people's tendency to avoid responsibility (Leonhardt et al., 2011; Beisswanger et al., 2003), likely due to the desire to minimize guilt and regret. Therefore increasing the level of responsibility would presumably result in stronger emotional input that enhances the effect of the context on choice.

The majority of studies investigating third-party risk decisions have mostly studied whether overall risk-taking is increased or decreased. Aggregating across feedback contexts (i.e. gains and losses taken together), we did not find any difference in risk-taking between deciding for the self and deciding for the third-party, and within the latter set for both cases of high and low responsibility, consistent with previous work (Stone et al., 2002). In other words, deciding for a third-party neither increases nor decreases *overall* levels of risk-taking, but it does significantly reduce the *difference* in risk preferences between gain and loss contexts in comparison to participants who made the same set of decisions for themselves. The finding that there was not an overall difference in risk-taking between the groups suggests that third-party risky decisions mainly impact the processing and weighting of the context, which in turn increases the impact of the context on subsequent risky choice. In line with this, previous studies have reported that negative and positive outcomes are processed less strongly when deciding for others (Kray & Gonzalez, 1999; Beisswanger et al., 2003).

The current findings provide several interesting avenues for future research. Decreasing one's personal economic involvement (i.e. self versus other) and one's level of responsibility for the decision may function as a form of regulating one's responses to rewards and punishments that might otherwise alter the way the task is played. Alternatively, taking a third-person's perspective may function to shift attention to the broader goal, thereby reducing context-dependent risk-taking. For example, loss aversion for individual choices decreased when individuals were instructed to "think like a trader", that is, to observe each small individual outcome as part of a larger portfolio (i.e. greater context), as compared to observing each outcome in isolation (Sokol-Hessner et al., 2009).

To conclude, in the current study we demonstrate that deciding for a third-party diminishes the inconsistency in risky choice for identical gambles following gains and losses. Furthermore, responsibility towards a third-party enhanced inconsistency in risk preferences, potentially by enhancing the emotional involvement in the choice process and thereby increasing one's susceptibility to the contextual effects. The current study provides additional insight into the largely understudied field of third-party risk-taking, by revealing differential effects of context (gains or losses) on risky choice.

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Third-party Cooperation

Abstract

Decisions to cooperate are often delegated to an authority or third-person that decides on the group's behalf whether they should either cooperate or not. Despite the importance and impact these decisions have on others, it is unknown whether these cooperative decisions are made differently compared to those made for oneself. In two studies we examined whether cooperative decisions might differ when decisions are delegated to others (i.e. third-party), and specify which motives are important for third-party social decision-making. Participants played multiple rounds of the Public Goods Game (PGG). In Study 1, personal involvement in the PGG was varied within-subjects, i.e. participants played a block for themselves ("Self"), a block for a third-party including oneself ("Shared"), and a block solely for a third-party ("Third-Party"). In Study 2, participants randomly played the PGG with either human players (i.e. social condition) or computer players (i.e. non-social condition), in blocks for themselves ("Self"), and solely on behalf of a third-party ("Third-party"). Participants contributed most when deciding on behalf of a third-party and when not personally involved in the outcome of the good, whereas participants contributed least when personal involvement was high (i.e. for Self). Additionally, these contribution amounts on behalf of a third-party were higher when playing with humans (social) as compared to when playing with computers (non-social). Differences in cooperation only occurred in the second block, when participants were able to base cooperation outcomes to a reference point, which was changed by personal involvement. Together, reducing personal involvement in the public goods game, when choosing for a partner or third-party, enhanced social interests, as shown by greater cooperation in social contexts as compared to non-social contexts. Furthermore, these higher cooperation amounts on behalf of a third-party might result from taking the other's perspective, thereby increasing social preferences.

Based on: Losecaat Vermeer, A. B., Heerema, R. L. & Sanfey, A. G. (*under review*). Third-party Cooperation: How reducing personal involvement enhances contributions to the public good.

Introduction

In 1997 representatives of multiple nations gathered together in Kyoto to negotiate a plan to combat global warming by reducing greenhouse gas emissions. The Kyoto protocol that was produced by this meeting essentially enlisted all citizens of the participating countries to cooperate in reducing their CO_2 levels, which of course in turn incurred financial costs to those citizens. However, at the same time, countries that did not sign this agreement could still enjoy the benefits of reduced global emissions (i.e. the so-called public good) without having to cooperate, outlining the risk of cooperation, namely that of being exposed to free-riders. This is just one of many examples that illustrates cooperative behaviour on a global scale, and demonstrates that these decisions generally involve evaluating different and conflicting motives, i.e. self-interest versus collective-interest.

Interestingly, many of these types of decisions, like the example described above, are not made by individuals themselves, but instead are delegated to an authority that decides on the group's behalf whether they should or should not cooperate. Despite the importance of these decisions and the often considerable impact that they have on each individual, the majority of research on cooperation has only studied how individuals make cooperative decisions for themselves. As illustrated in the example above, cooperative decisions can entail different levels of personal involvement in both the decision and the outcome of the public good. This can be full involvement (i.e. which we refer to as the "Self"), for example, deciding for oneself whether to cooperate in a public good such as reducing greenhouse gases, and personally reaping the benefits. A more moderate level of involvement would be the example of representatives of nations deciding to participate in the Kyoto protocol. These situations entail a joint involvement in both the decision and outcome of the public good. In other words, a person who decides whether to cooperate on behalf of another person or a group, which includes himself, we refer to here as a "Shared third-party" decision. Finally, there is the situation in which a person decides whether to cooperate solely on behalf of another person or group whilst having no personal involvement in the outcome of the decision; for example, a judge deciding how a divorced couple should cooperate in the fair division of property, which we refer to here as a "Third-Party" decision.

In this study, we are interested firstly in whether cooperative decisions are made differently when the decision-maker is making choices for a third-party, i.e. for another person, as compared to when making choices directly for themselves. Secondly, we are interested in which direction these differences lie; assuming they exist – are third-party decisions more pro-social or more pro-self? Finally, we attempt to specify which motives are important for third-party decision-making, and how these might affect the social preference of cooperation.

Whether cooperative decisions are made differently on behalf of a third-party is, to date, an open question. However, a few studies on risk-taking and social preferences highlight potential behavioural differences for third-party decision-making as compared to when similar decisions are made on behalf of the first-person (i.e. for the self), providing some helpful insights into how they may influence decisions in cooperation.

The majority of research in the area of third-party decision-making has been conducted in the context of medical choices, a good example of the decision-maker not being directly involved in the outcome. One typical study demonstrated that doctors tend to take less risk when deciding on behalf of a patient considering a risky or a safer treatment, as compared to when they make the same decision for themselves (Garcia-Retamaro & Galesic, 2012). Furthermore, third-party decisions concerning uncertain outcomes (i.e. monetary gambles) show different patterns of behaviour relative to first-person decisions. For instance, studies found that participants made more risk averse choices in settings in which they had joint involvement, such as for deciding for a partner and themselves (Charness & Jackson, 2009), or a group in which they were part of (Reynolds et al., 2009). Conversely, other studies found increased uncertainty-seeking in hypothetical settings concerning other peoples' outcomes, which correlated with reduced responsibility (Leonhardt, Keller & Pechmann, 2011). These differences have been attributed to participants' aversion to take responsibility when choosing on behalf of another person. In a prior study from our group (Losecaat Vermeer et al., submitted (chapter 4)), we examined how the degree of involvement in the outcome of the decision can alter risk preferences as a function of prior gain and loss framing contexts. We found that risk-taking preferences for monetary choices were less susceptible to prior monetary gain/loss contexts (i.e. a framing effect) when choosing for third-parties, with the susceptibility decreasing as involvement for the decisions decreased. This shows that personal involvement in the outcome of the decision can alter choice preferences, resulting in different decisions when personal involvement is low, i.e. choosing for a third-party, than when personal involvement is high, i.e. choosing for the self. Thus, this suggests that people may have different preferences for cooperation when deciding on behalf of a third-party.

Some studies have examined if third-party choice alters social preferences (Pronin, Olivola & Kennedy, 2008; Beisswanger et al., 2003; Trautmann & Vieider, 2011). For example, when deciding for others people demonstrate a preference for choice options with high desirable and low feasible outcomes (e.g. a better restaurant which is further away) rather than options with less desirable but highly feasible outcomes (e.g. a lower quality restaurant, but close-by) (Lu et al., 2013). In line with these results, for monetary gambles temporal distance was found to increase the influence of payoffs (i.e. desirability) and to decrease the influence of probability (i.e. feasibility) on preferences (Sagristano et al., 2002). A similar result has also been observed for choices between sooner smaller and later larger rewards, with greater preferences for the delayed reward for others than for oneself (Albrecht et al., 2011; Kim, Schnall & White, 2013). However, other studies have found no difference between third-party and first-person decisions (Stone et al., 2002; Civai et al., 2010; Corradi-Dell'acqua et al., 2013). For instance, decisions on behalf of a third-party regarding fairness demonstrated an equal preference for fairness to when the offer was directed to the individual herself (Civai et al., 2010; Corradi-Dell'acqua et al., 2013). Though not yielding a behavioural effect, these studies did show a difference in the underlying neural processes, suggesting that the decision-maker's role does indeed have some impact. For example, the strong negative affective response that occurs when receiving unfair offers for oneself was absent when receiving these offers on behalf of a third-party (Civai et al., 2010), and activity in reward and affect-related brain regions for third-party decisions was diminished relative to self choices (Civai et al., 2010; Albrecht et al., 2011; Corradi-Dell'acqua et al., 2013). This suggests that affective and reward-related responses involved in social decision-making are weaker, or even absent, when the decision-maker is not directly involved in the outcome of the choice. Taken together, the research literature regarding third-party decision-making has shown that choice preferences can differ when choosing for a third-party compared to choices made for the self, both behaviourally as well as in underlying brain processes. Specifically, the extent of personal involvement of the decision-maker plays an important role in both preferences for risk as well as social preferences.

In this study we were interested in examining whether the reported differences in the third-party literature also apply to cooperative decisions. One behavioural model is that cooperative decisions for third-party are the same as for first-person, in line with some previous research (Civai et al., 2010; Stone et al., 2002). Third-party decisions might be taken with a self-perspective, that is, deciding for others as we would decide for ourselves. Alternately, third-party decisions may cause the individual to take the perspective of the other person, which might result in using different decision rules, and thereby altering decision preferences of cooperation.

To study this model of third-party cooperation, we used the Public Goods Game (PGG) (Samuelson, 1954; Andreoni, 1988). This is an experimental task adopted from classical Game Theory, which models strategic behaviour in social contexts via simple economic paradigms (Von Neumann & Morgenstern, 1944). In the standard PGG (our "Self" condition), a group of players each receive a monetary endowment, and then all have to decide simultaneously how much, if any, of this amount they are willing to contribute to a public pot, keeping the remainder for themselves. The total sum of the pot is then multiplied by a reward factor (usually 1.6) and this 'public good' is then redistributed equally across all players, irrespective of how much each individual has contributed. After all participants have decided, the payoff of the pot is revealed and a new round starts. Similarly to public goods in real life (e.g. clean air or public parks), all participants receive an equal share of the public good, regardless of how much each individual decides to contribute (i.e. personal cost) in providing the good. In the condition in which the decision-maker is jointly involved in the public good outcome ("Shared"), the decision-maker decides how much to contribute on behalf of a selected player, and shares both the endowment and outcome of the public good with their partner. In the "Third-Party" condition, the decision-maker also decides on behalf of a selected player, similar to the Shared condition, however in this case the decision-maker is not involved in the outcome of the public good.

A player who seeks to maximize his profit should contribute less than the average, or even nothing at all (free-ride), which typically results in receiving the highest payoff. Conversely, a cooperator is a player that accepts a higher personal cost for the benefit of the collective, by contributing the average amount or higher. A great deal of research using the PGG has demonstrated that people do not simply maximize their own economic gain (Camerer, 2003), but do care about others' payoffs, and data indicates that people contribute on average around 40% of their initial endowment to the public pot (Fehr & Gächter, 2000; Fischbacher et al., 2001). Thus, social motivations are important in determining cooperation. In situations when these decisions are made on behalf of others it is unclear if, and how, these motives influences cooperation. For example, third-party decisions may in addition elicit a form of responsibility for the decision and outcome of the good, both toward the group and the beneficiary.

The aim of this study is twofold. The *first aim* is to explore third-party cooperation, that is, to assess if cooperative decisions change as a function of whether the decision-maker is materially involved in the outcome or not. If there are differences depending on the role of the decision-maker, one possible outcome is that cooperation levels might increase when deciding on behalf of someone else. Reducing material involvement by deciding for a third-party might reduce self-interest. Studies on cooperation (for self only) have shown that the ability of people to focus on long-term benefits by overriding short-term self-interest induced higher levels of contributions (Rilling & Sanfey, 2011). In line with previous studies on third-party showing less impulsive behaviour (Albrecht et al., 2011; Kim et al., 2013; Lu et al., 2013), this suggests that third-party cooperative decisions might result in higher contribution levels. Alternatively, third-party cooperative choices may show reduced contribution levels as a result of an aversion to take responsibility and risk for another (Charness & Jackson, 2009; Reynolds et al., 2009; Leonhardt et al., 2011). In a strategic game such as the PGG, the social uncertainty of reciprocation as well as the responsibility for deciding for a third-party might actually result in the avoidance of the risk of cooperating, and as a result in choices of the safer option to defect or free-ride. The *second aim* is to identify motives relevant for cooperation, and specifically for third-party cooperation, by examining whether peoples' willingness to cooperate on behalf of a third-party is altered when varying the social context of the group. We examined cooperation for first- and third-parties, in a social context (e.g. affecting other human players) and in a non-social context (e.g. affecting purported computer players). This will help us decompose the fundamental motives that guide our preferences to cooperate, and test if third-party cooperation is driven by enhanced social preferences or rather triggered by other factors (e.g. risk preferences).

Based on previous literature on third-party decision-making, third-party cooperation decisions might increase with decreasing personal involvement. Decreasing personal involvement in the outcome of the decision for a third-party may reduce the impact of the uncertainty of reciprocation, and a preference towards outcomes that are beneficial for the collective. On the other hand, if cooperation levels for social as well as non-social players are the same, then this suggests that preferences for risk may play a more prominent role than social preferences in determining cooperation. In the second study therefore, we can isolate these motivations by exploring the willingness to cooperate for self and for third-party when playing against both human players (social context) and computer players (non-social context).

To answer the aforementioned questions, participants played multiple blocks, and within each block multiple rounds, of the PGG, under various different conditions. In the first study, we manipulated the personal involvement in the PGG, within-subjects: participants played a block for themselves ("Self"), a block for themselves and a third-party ("Shared"), and a block solely for a third-party ("Third-Party"). In the second study, participants randomly played the PGG with either human players (i.e. social condition) or computer players (i.e. non-social condition), in blocks for themselves ("Self"), and solely on behalf of a third-party ("Third-party").

Materials and Methods Study 1

Participants

60 volunteers participated in the study. All gave written informed consent and received research credits for participation. Participants could earn a monetary bonus (between €0 - €10) depending on their performance in a selection of rounds that they played on their own behalf and rounds that another player played on their behalf. Experimental exclusion criteria were self-reported history of psychiatric disorders, regular use of marijuana, or use of psychotropic drugs. One participant (male) was excluded because of reported daily drug use. Data is therefore reported from 59 participants (Male = 17, M = 22.67 years, SD = 2.82). The study was approved by the local ethics committee.

Design

We employed a modified version of the Public Goods Game (PGG; Fehr & Gächter, 2000) to study cooperative decisions. Three PGG conditions were used; 1) participants played the task for themselves, in which case their total earnings from the public pot would then be paid out to them (*Self)*, 2) participants played the task on behalf of themselves and a randomly selected, anonymous, player ('partner'), in which case their total earnings from the public pot would be split between the participant and his partner (*Shared)*, and 3) participants played the task on behalf of a randomly selected, anonymous, player, in which case the other player would receive the total earnings from the pot and the decision-maker did not receive anything (*Third-Party)*. Participants were told that when they would be playing on behalf of another player, that another participant in turn would be playing for him/her.

At the beginning of the task participants were shown the beneficiary for whom they would play. Importantly, they did not know about the other conditions in advance, to avoid inducing use of a fixed strategy. Participants played all three conditions, with each condition consisting of 20 experimental rounds, and 60 experimental rounds in total. Order of conditions was counterbalanced across participants, resulting in a total of 6 possible orders, distributed equally across participants. A total of 19 participants started in the *Self* condition, 20 participants started in *Shared* condition, and 20 participants in the *Third-Party* condition.

Procedure

After the instructions of the modified PGG, participants first filled in a questionnaire to ensure that they understood the task completely. At the beginning of the experiment, participants were told that their bonus would be paid out at the end of the entire study (i.e. when all participants had played the game). Therefore, no feedback was given about the income of the pot and the outcome of each round the participants played for the respective beneficiary. Participants were told that they would play three blocks of the game, with some extra instruction given before the start of a new block. Because participants were not informed in advance that they would also be playing for different beneficiaries, all participants were told that in each block one round would be selected randomly and the total earned tokens in those rounds (i.e. tokens kept plus an equal share of the pot) would be converted to Euros and paid out at the end of the study. The conversion rate of a token was not announced in advance in order to avoid nudging players into merely adopting a profit-maximizing strategy (Andreoni, 1988).

At the start of the experiment participants saw the beneficiary they would be playing for. In the *Self* condition, a silhouette with the text "You" was highlighted. For both the *Shared* and *Third-Party* condition, one player with a random ID number was selected from a pool of 24 players at the start of the block, and was highlighted as the partner or other player, respectively. The selected player stayed the same throughout the block.

At the start of each trial (i.e. PGG round), participants saw a fixation cross (1000 ms), followed by a screen where a yellow box selected three other players randomly from the pool of the remaining 23 players. The selected players were the group players for that round with whom the participant would share the public pot. After the selection of the group players, a contribution screen was presented and participants had 8 seconds to indicate how much of their endowment, if any, they wanted to contribute to the public pot. If the endowment was 10 tokens, participants could indicate an amount between 0-10 (with steps of 1) to contribute to the pot. If they received 20 tokens as endowment, they could choose any amount between 0-20 (with steps of 2) (see Figure 1). The endowment amount per round was randomly determined. After confirming their choice, a screen indicating that their contribution was saved was presented and a new round began after a random time interval. If the participants did not confirm their choice within 8 seconds, the round ended with a warning message reminding participants to respond within 8 seconds. On each round three other players were randomly selected from the same pool of 23 players.

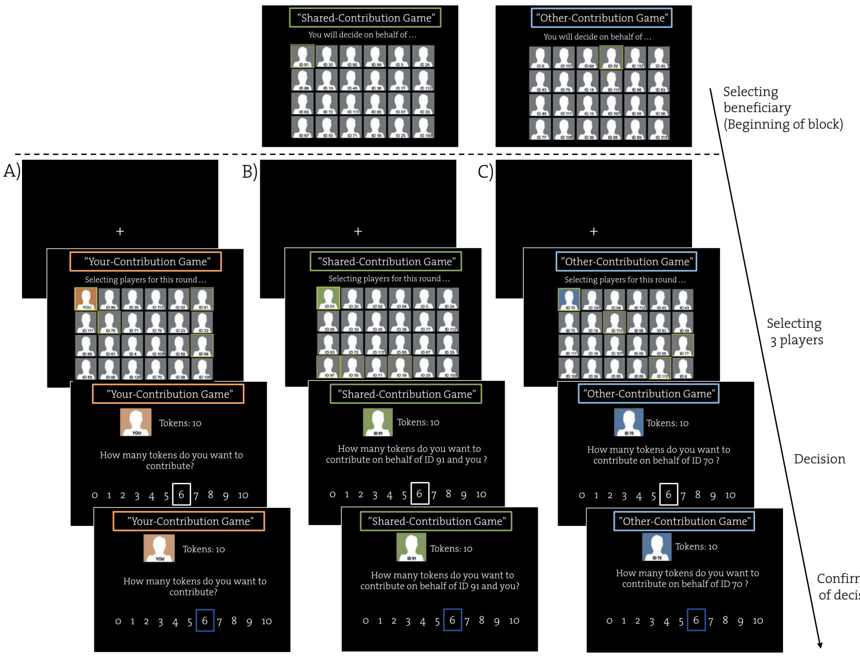

Fig. 1 Modified Public Goods Game. Each round begins by randomly selecting 3 group players with whom the beneficiary will share the public good. Next, participants will see their endowment (tokens) and asked to indicate how many tokens they would be willing to contribute. After confirmation of the selected amount, the game round ends after which a new round starts. No feedback is given. A) The *Self* PGG. An example of a round played for the Self. B) The *Shared* PGG. At the beginning of the block, the partner for whom the decision-maker will choose to cooperate is selected, and stays the same over the entire block. C) The *Third-Party* PGG. Participants choose on behalf of another person, whom is also selected at the beginning of the block.

At the beginning of each new block of the PGG, participants received extra instructions introducing the new beneficiary of that PGG, including the implications to the payoff of the pot. Each block began with 4 examples of possible scenarios, followed by 2 practice rounds; analogous to the instruction of the first condition they played.

In total, participants played 60 experimental trials, 20 trials per condition (*Self, Shared*, and *Third-Party*), per block. The task was presented in Psychophysics Toolbox (Brainard, 1997; Pelli, 1997) running on MATLAB® R2011b (The MathWorks). After finishing the PGG, participants completed a questionnaire online (Qualtrics

Software, 2014) about the task, such as their expectations and beliefs, and demographics. All participants had to return to receive their payments.

Analysis

In order to assess the level of cooperation per condition, we assessed the proportion of tokens contributed on each trial as the dependent measure (continuous variable from 0 – 1). We included four within-subject factors: 'beneficiary by personal involvement' (three levels: Self, Shared, Third-Party), 'endowment' (two levels: 10 or 20 tokens), and also the start position of the contribution box 'startposition' (continuous variable of 11 positions from 0-10) and 'block' (Three levels: first, second, and third block). Reaction times were measured in seconds (fixed interval: 0-8 seconds), and outliers were determined and excluded from analysis by means of the number of key presses that were at least 3 standard deviations from the median using Hampel identifier approach (14 trials with 14 key presses or more were excluded). All behavioural statistics were computed using the R statistical package (R Development Core Team, R version 3.1.2. (Pumpkin Helmet), 2014). A linear mixed effect model was performed, using the *mixed* function of the package (afex, v.0.12-135) for Analysis of Factorial Experiments (Singmann, 2014), running with lme4 (v.1.1-7) (Bates, Maechler, Bolker & Walker, 2014). The model contained the four within-participant factors to predict participant's willingness to cooperate (continuous variable from 0 – 100%). To account for the repeated-measures of the data, a random adjustment of each participant was allowed to vary to the fixed intercept, by including a random intercept by subject in the model (e.g. Baayen, Davidson, & Bates, 2008). Within-unit random slopes for within-subject effects (i.e. 'Beneficiary' and 'Endowment') were included. Significance levels were calculated with the Kenward-Roger (KR) correction implemented in the *mixed*() function (Singmann, 2014) For all post-hoc pairwise multiple comparisons and descriptives (i.e. least-squares means, 95% confidence intervals (CI)), we used the *lsmeans* function of the lsmeans package (v.2.13) (Lenth, 2014).

Results Study 1

Cooperation levels by personal involvement: on behalf of Self, Partner (Shared), and Third-party

Participants on average transferred 49.7% of their endowment to the public pot. Of most interest to this study was whether the level of personal involvement in the outcome of the public pot (beneficiary) influences how much individuals would be willing to cooperate with other players, as defined by contribution

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amounts. Indeed, personal involvement significantly affected cooperation levels ($F(1, 54.04) = 5.44$, $p = .007$). That is, the amount of cooperation was higher when there was no personal involvement in the outcome (i.e. Third-Party) ($M_{\text{Third-Party}} = 0.561$, $CI = [0.489, 0.633]$), as compared to when personal involvement was highest (i.e. Self) ($M_{\text{Self}} = 0.444$, $CI = [0.386, 0.503]$; Cooperation $_{\text{Third-Party – Self}}$ $t(55.66) = 3.094$, p = 0.009). Deciding on both the self and the third-party's behalf (i.e. Shared) resulted in a marginally lower cooperation amount relative to the Third-Party condition ($M_{\text{Shared}} = 0.486$, $CI = [0.424, 0.549]$, Cooperation $_{\text{Third-Party – Shared}}$ $t(55.44) = 2.126$, p=0.093), and a marginally higher cooperation amount relative to the Self (Cooperation $_{\text{Shared – Self}}$ $t(54.62) = -2.331$, p =0.060) (Figure 2).

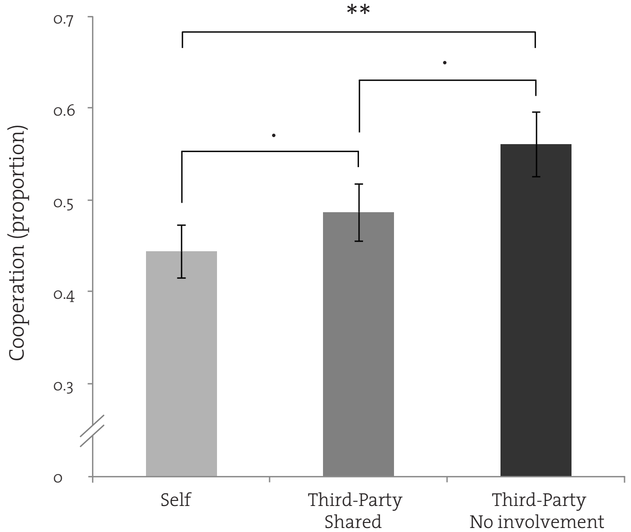

Fig. 2 Cooperation level across conditions of personal involvement. Error bars are one +- standard error of the mean. · $p < .10$, ** $p < .01$

Participants contributed fewer of their tokens when endowed with 20 tokens ($M_{\text{20 tokens}} = 0.485$, $CI = [0.430, 0.539]$) as compared to 10 tokens ($M_{\text{10 tokens}} = 0.510$, $CI = [0.456, 0.564]$) ($F(1, 58.69) = 5.12$, $p = 0.03$), which was the same for all conditions ($F(2, 3270.55) = 1.85$, $p = 0.16$). Furthermore, when examining cooperation in only the first block, that is between-subjects, cooperation amounts did not differ between conditions, $F(1, 10.26) = 1.85$, $p = .21$ ($M_{\text{Self}} = 0.400$, $CI = [0.235, 0.565]$; $M_{\text{Shared}} = 0.454$, $CI = [0.353, 0.555]$; $M_{\text{Third-Party}} = 0.549$, $CI = [0.445, 0.651]$), demonstrating no significant difference in cooperation between different levels of personal involvement.

Reaction times of cooperation: on behalf of Self, Partner (Shared), and Third-Party

We tested whether beneficiaries with different levels of personal involvement affected reaction times for decision to cooperate, which could imply a difference in difficulty in processing the decision for different beneficiaries. No differences in reaction time for Self (M = 3.242, CI = [3.008, 3.476]), Shared (M = 3.297, CI = [3.055, 3.539]), and Other (M = 3.147, CI =[2.888, 3.407]) was observed, ($F(2, 1252.14) = 1.39$, $p = .25$. Participants became faster in decision-making over time ($F(2, 98.8) = 22.93$, $p < .001$; $M_{block1} = 3.525$, CI = [3.280, 3.770], $M_{block2} = 3.218$, CI = [2.973, 3.463], M_{block3} = 2.943, CI = [2.698, 3.189]), which was the same for all beneficiaries ($F(2, 105.35) = 0.85$, $p = .50$).

Conclusion Study 1

In this experiment we examined if cooperation levels were influenced by the extent of personal involvement in the public good. We varied the involvement in the public good, looking at when a participant decided how much he/she was willing to contribute for herself (i.e. standard PGG; *Self)*, for a partner in which the decision-maker and partner split the payoff of the public good (*Shared)*, and for a third-party in which the decision-maker was not involved in the outcome of the public good (*Third-Party)*. Firstly, we found that participants contributed, on average, 50% of their own endowment, following closely with other studies of cooperation (Fehr & Gächter, 2000). Participants were more willing to cooperate on behalf of a third-party as compared to cooperating for themselves. Moreover, when participants had to decide how much to cooperate on behalf of a third-party in which they shared the total income of the pot, participants contributed less as compared to not being materially involved in the public good (*Third-Party*). However, they still cooperated more in comparison to being directly involved in the payoff of the pot, that is, when cooperating with only themselves as the beneficiary. These results indicate that reducing self-related interests and enhancing focus on the other beneficiary's payoff, by choosing on behalf of a third-party, increases cooperation. In other words, people potentially place more weight on social values when personal involvement is reduced. Moreover, preference to cooperate across personal involvement did not differ at the first block. That is, when no comparison between levels of involvement could be made, cooperation amounts were the same. This suggests that at first, people use a

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"default" decision preference to cooperate, and when the situation changes to more or less involvement, the new situation is compared to the prior situation and decision preferences are updated.

Study 2. Third-Party cooperation for social and non-social contexts

In the first study we investigated how reducing material involvement in the public good encourages cooperation. Decreased material involvement is hypothesized to enhance social preferences underlying cooperation, such as the preference to abide by social norms and rules (Fehr & Fischbacher et al., 2004a). However, the PGG used in Study 1 always contained a social component, that is, the group were always human players with whom the outcome of the public good was determined and shared. To examine whether increased cooperation on behalf of a third-party is driven by pure social motives (e.g. collective benefit) and not other self-related motives (e.g. risk or reputation), we included a *non-social* group (computer players) and a *social* group (human players). In addition, we compared only cooperative decisions for a third-party in which the decision-maker was not materially involved (*Third-Party*), with the standard PGG in which the decision-maker decides for themselves and is materially involved in the outcome. The rationale to examine only the two conditions is because these showed the largest differences in cooperation in the first study. In Study 2 we aimed to replicate the findings of Study 1, that is, enhanced cooperation on behalf of third-party, and additionally examine whether this is strongest for social or non-social groups.

Materials and Methods Study 2

Participants

47 volunteers participated in the study. All gave written informed consent with 10, taking part for course credit while the remaining received €10 for participation. Participants could earn a monetary bonus (between €0 - €5) depending on their performance in a selection of rounds that they played on their own behalf, and rounds that another player played on their behalf. The average bonus paid was 1.33. Experimental exclusion criteria were a self-reported history of psychiatric disorders, regular use of marijuana, or use of psychotropic drugs, and elaborate foreknowledge about the nature of the experiment. One participant was excluded because she had just taken part in a similar public goods game study; one other

participant was excluded due to technical problems. Data is therefore reported from 45 participants (7 males, M = 21.33 years, SD = 2.45). The study was approved by the local ethics committee.

Design

In this experiment we used a similar version of the PGG employed in Study 1. In Study 2 we investigated two conditions, "Self" versus "Third-Party", as outlined in Study 1. Again, the other player was an anonymous other player who was randomly selected at the beginning of the game and remained the beneficiary of the participant throughout the experiment.

The critical addition to this experiment is the group composition (which we refer to here as context). Here, we directly compared cooperation decisions in social versus non-social contexts, by including a group of computer players (i.e. non-social context) in addition to the original paradigm with anonymous human players (i.e. social context) with whom the public pot was shared. Participants were told that the computer players followed 'pre-programmed strategies', and were presented as computer logos (see Figure.3).

Procedure

The procedure of Study 2 was similar to Study 1. Instructions of the task, and rules of bonus payment were similar and made clear from the beginning. Again, participants were told that the other human players were participants in the experiment who either already participated or still had to participate in the game. No feedback was given about the outcome of each round.

Participants were told that they would play two blocks of the task. Participants played one block only for the Self and one block only for a Third-Party, counterbalanced. The different group contexts (social and non-social) were randomized within each block. Brief instructions were given before the start of a new block. Similar to Study 1, participants were not informed in advance that they would be playing for different beneficiaries.

After the instructions participants performed four practice trials: with a 10- and 20-token initial endowment, and with a "Social" and "Non-social" group. In the same way as Study 1, participants first saw the beneficiary they would be playing for, either as a silhouette with the text "You" (*Self* condition), or as a silhouette with a random ID number (*Third-Party* condition), who was randomly selected from a pool of 24 players at the start of the block. Participant had to confirm that they understood they would be playing for this person throughout the experiment.

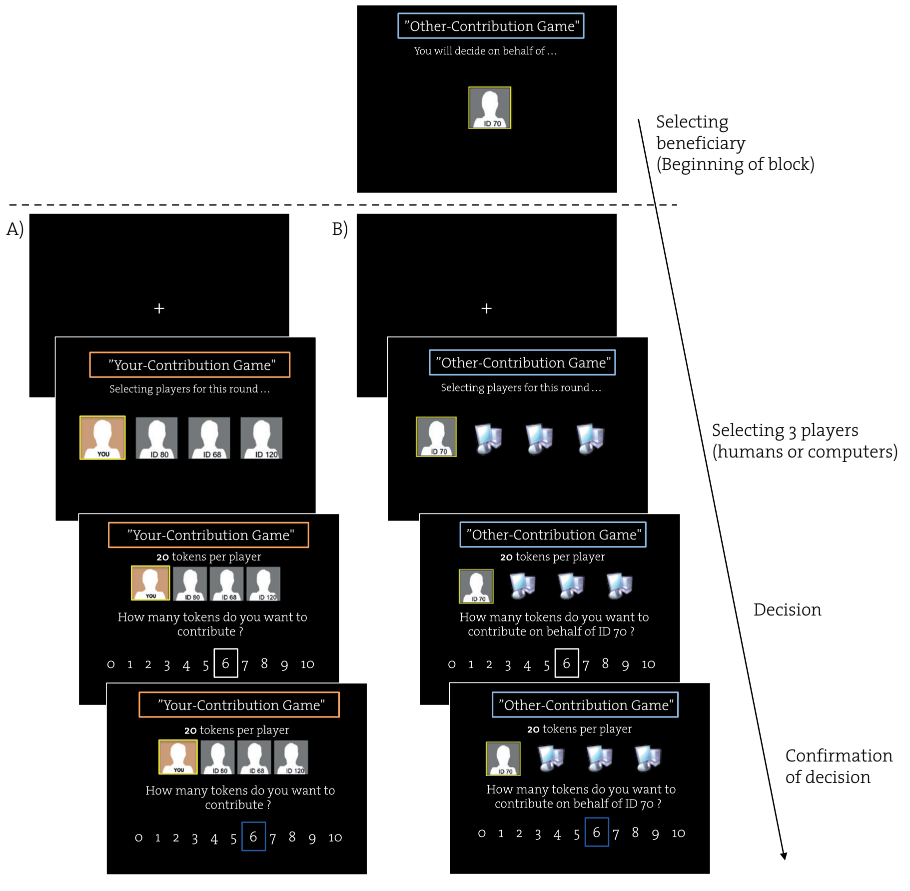

Fig. 3 Modified Public Goods Game with social and non-social group context. Each round begins by randomly selecting 3 group players with whom the beneficiary will share the public good. Next, participants will see their endowment (tokens) and asked to indicate how much they would be willing to contribute. After confirmation of the selected amount, the game round ends after which a new round starts. No feedback is given. A) The *Self* PGG. An example of a round played for the Self in the social context (with human players). B) The *Third-Party* PGG. At the beginning of the block, the other person is selected for whom the decision-maker will choose to cooperate for multiple rounds. An example of a round played for the third-party in the non-social context (computer players) is shown.

At the start of each trial (i.e. PGG round), participants saw a fixation cross (500 ms). They were then informed about the composition of their group in the round to come. A non-social group was depicted by three computer logos, while in a social group there were three silhouettes with anonymous ID numbers randomly selected from a pool of other participants' ID numbers. Upon a keystroke for confirmation, the contribution screen appeared. Participants could then indicate how much of the initial endowment, if any, they wanted to contribute to the public pot. The selection of amount was the same as experiment one.

Upon completion of the first block, participants were informed they would continue in a second block. They were introduced to the new beneficiary of the PGG and shown the rules of the game again. Importantly, participants did not know in advance that they would be playing on behalf of someone else if they had started in the *Self* condition, and vice versa. In total, participants played 80 experimental trials, 40 trials per condition (*Self*, *Third-Party*), per block. Participants were endowed at the start of each round with either 10 or 20 tokens, randomly selected across trials, and participants shared the public pot with non-social groups and social groups (20 trials per group context in each block). The task was presented in Psychophysics Toolbox (Brainard, 1997; Pelli, 1997) running on MATLAB ® R2011b (The MathWorks).

After finishing the PGG, participants were shown the ID number of the player that had played on their behalf. Subsequently, they were asked to select six rounds out of all the rounds played, by means of six keystrokes while trial numbers randomly flashed on the screen, that would be used to calculate their bonus. Three of these rounds corresponded to the participant's trials from the *Self* condition, while the three other rounds corresponded to trials from the anonymous person that had formerly played on the participant's behalf in the *Third-Party* condition. Before the calculation of the bonus participants completed an online questionnaire (Qualtrics Software, 2014) about the task, similar to Study 1.

After the questionnaire, the bonus was paid out, which was based on six randomly selected rounds. Only rounds played with computer players were selected for payment, because not all the participants had participated yet. The average total balance of these six rounds determined whether participants received a bonus between €0 - €7.50. In total, the experiment lasted about an hour.

Analysis

In order to assess the level of cooperation, the proportion of tokens contributed on each trial was used as the dependent measure (continuous variable from 0 – 1). To predict participant's willingness to cooperate, we included five within-subject factors: 'beneficiary' (two levels: Self, Third-Party), 'group context' (two levels: social, non-social), 'endowment' (two levels: 10 or 20 tokens), the start position of the contribution box 'startposition' (0-10) and 'block' (two levels: first and second). To account for the repeated-measures of the data, random adjustment of each participant was allowed to vary to the fixed intercept, and was included as a random intercepts by subject in the model (e.g. Baayen, Davidson, & Bates, 2008). Within-unit random slopes for within-subject effects (for 'beneficiary', 'group context', 'endowment') were included. Behavioural analyses were computed identically to Study 1. Reaction times were measured in seconds (fixed interval: 0-8 seconds), and outliers were determined and excluded from analysis by the same procedure as study one (trials with 12 key presses or more were excluded, in total 45 trials). For all post-hoc pairwise multiple comparisons and descriptives (i.e. least-squares means, 95% confidence intervals (CI)), we used the *lsmeans* function of the lsmeans package (v.2.13) (Lenth, 2014).

Results Study 2

Cooperation levels with social and non-social groups: on behalf of Self and Third-Party

Replicating results from Study 1, participants contributed significantly more tokens on behalf of a Third-Party than for themselves (Self), $F(1,43.37) = 13.68$, $p < .001$ ($M_{\text{Third-Party}} = 0.473$, $CI = [0.429, 0.516]$, $M_{\text{Self}} = 0.368$, $CI = [0.322, 0.414]$). Cooperation amounts were not higher when playing with human players (social context) as compared to playing with computer players (non-social context), $F(1, 44.01) = 1.54$, $p = 0.22$, There was a significant interaction observed between beneficiary and context of the group ($F(1, 3346.24) = 19.15$, $p < .001$) (Figure 4). That is, participants contributed more on behalf of the Third-Party with human players (social context) as compared to with computer players (non-social context) ($M_{\text{social-nonsocial}} = 0.066$, $t(47.70) = 2.089$, $p = 0.042$), whereas contribution levels for oneself was not influenced by the group context ($M_{\text{social-nonsocial}} = 0.011$, $t(47.76) = 0.342$, $p = 0.734$). Furthermore, participants contributed more for the Third-Party relative to the Self in the social context, $t(47.72) = 4.560$, $p < .001$, and also more in the non-social context, $t(47.77) = 2.662$, $p = 0.01$ (see Figure 4). After the task, participants were asked to rate the importance of cooperation with humans and with computers (on a slider from 0-100). Participants rated the importance of cooperation with humans ($M = 56.4$) significantly higher than cooperation with computers ($M = 35.5$): $t(91.558) = 4.205$, $p < .001$.

Participants' initial contribution amount in the first block, on average, was the same irrespective of contributing on behalf of a third-party or the self ($M_{\text{Other}} = 0.429$, $CI = [0.366, 0.492]$; $M_{\text{Self}} = 0.407$, $CI = [0.342, 0.472]$), $F(1, 42.98) = 0.021$, $p = 0.886$. However, in the second block, when participants switched cooperative decisions by beneficiary (from Self to Third-Party, and Third-Party to Self) a significant change in cooperation levels was observed, $F(1, 43.00) = 5.43$, $p = 0.025$. Specifically, participants who started in the Self condition (and therefore had the

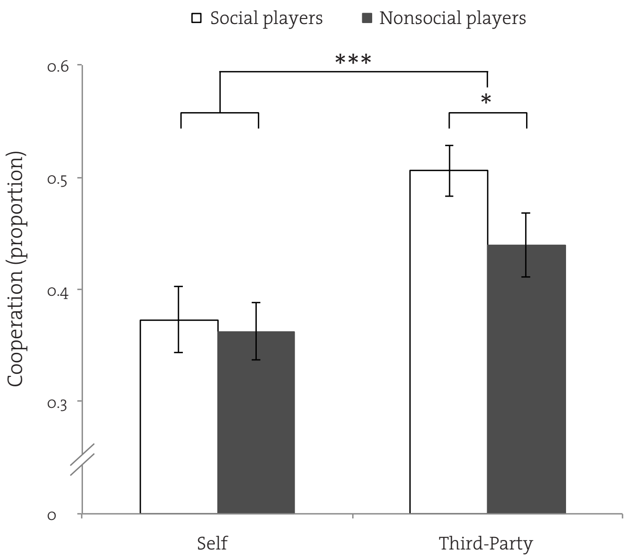

Fig. 4 Cooperation levels by personal involvement (Self and Third-Party) and group context (Social and Non-social). Error bars are one +- standard error of the mean. * p <.05, *** p <.001

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Third-Party condition second, N = 23), cooperated 10.9% more for a Third-Party in the second block (i.e. Third-Party condition, $M_{\text{Self Block 1}} = 0.407$, CI = [0.342, 0.472], $M_{\text{Third-Party Block 2}} = 0.516$, CI = [0.454, 0.578], $t(45.52) = 2.762$, $p = 0.04$). The participants who started in the Third-Party condition (and had the Self condition second, N = 22) cooperated 10.1% less when then cooperating for the Self in the second block, which trended towards significance ($M_{\text{Third-Party Block 1}} = 0.429$, CI = [0.366, 0.492], $M_{\text{Self Block 2}} = 0.328$, CI = [0.262, 0.394], $t(45.46)=2.502$, $p = .073$) (Figure 5).

Participants contributed fewer tokens when endowed with 20 tokens ($M_{\text{20 tokens}} = 0.401$, CI = [0.365, 0.437]) as compared to with 10 tokens ($M_{\text{10 tokens}} = 0.439$, CI = [0.403, 0.475]), $F(1, 43.93) = 14.93$, $p < .001$, which was the same for all conditions, $F(1, 3327.53) = 0.152$, $p = 0.697$.

Reaction times of cooperation: on behalf of Self and Third-Party

We tested whether the beneficiary for whom participants decided affected reaction times for decision to cooperate. Reaction times did not differ depending for whom participants were deciding ($F(1, 42.99) = 0.50$, $p = .48$). However, participants' decisions were slower when playing with human players as compared to computer players ($M_{\text{Humans}} = 3.060$, CIs = [2.811, 3.310]; $M_{\text{Computers}} = 2.928$, CIs = [2.698, 3.158]), $F(1, 43.90) = 8.00$, $p = .007$. Participants were faster at making

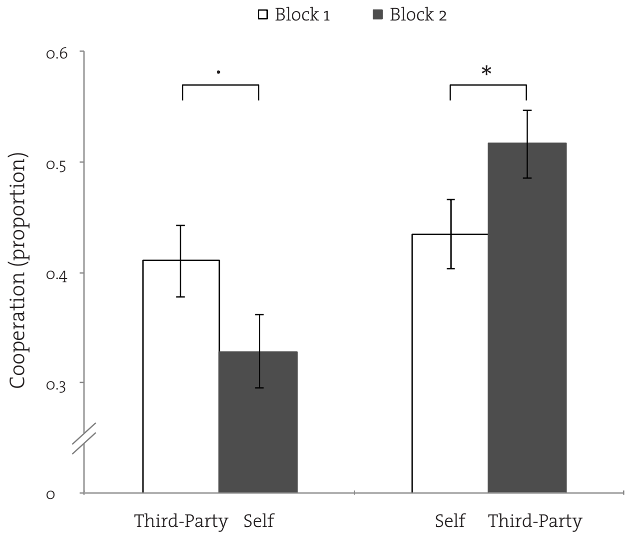

Fig. 5 Cooperation levels by personal involvement (Self and Third-Party) per block. Participants whom began cooperating for the Self, then cooperated on behalf of a third-party in the second block, and vice versa. Error bars are one +- standard error of the mean. · p <.10, * *p* <.05

decisions in the second block as compared to the first block ($M_{\text{Block 1}}$ = 3.258, *CIs* = [3.007, 3.508], $M_{\text{Block 2}}$ = 2.730; *CIs* = [2.479, 2.982]), $F(1, 42.99) = 33.59$, $p < .001$. Moreover, decision times for each block were not influenced depending for whom the decision was made, $F(1, 42.99) = 3.49$, $p = .07$).

Conclusion Study 2

We again showed that varying the involvement in the public good by means of choosing either on behalf of oneself or for a third-party influenced the willingness to cooperate. Individuals contributed more on behalf of a third-party than when choosing for themselves. Notably cooperation amounts between Self and Third-Party only differed in the second block of the PGG. Specifically, participants who cooperated first for the Self in block 1 and then on behalf of a Third-Party in block 2, contributed 11% more on average when cooperating for another person. Participants whom cooperated first for the Third-Party in block 1 contributed 10% less when cooperating for the self in block 2. In other words, preference to cooperate across personal involvement did not differ at the first block, similar to Study 1. However, when personal involvement changed to more or less involvement, decision preferences were compared to the previous situation and updated accordingly. The social and non-social group context affected cooperation amounts on behalf of third-party, though not when participants played on own behalf. That is, participants contributed more tokens on behalf of a third-party when the public good was shared with other human players (i.e. social context) than when it was shared with computer players (i.e. non-social context). Furthermore, cooperation with humans was rated as more important than cooperation with computers, which was also reflected in reaction times.

General discussion

The main question of interest in the current study was to examine whether the degree to which the decision-maker is affected by the outcome of a cooperative interaction would influence contribution amounts in a Public Goods Game. We examined this by comparing choosing for oneself as compared to choosing for a third-party, as well as an intermediate condition where both the decision-maker and their partner benefitted equally. Additionally, we examined whether willingness to cooperate is impacted by both social and non-social group contexts. Large-scale cooperative decisions are often made by individuals on behalf of other people (i.e. third-party), hence it is of immediate interest to understand how these decisions are made in comparison to standard individual cooperative decisions.

Results demonstrated clearly that cooperative behaviour was at its maximal when deciding on behalf of a third-party, as compared to when deciding for a third-party and being jointly involved in the public good, as well as when only deciding for oneself. In other words, when material involvement in the decision is reduced, self-related strategic interests are correspondingly reduced, and social preferences are thus enhanced which resulted in a greater extent of cooperative behaviour. This result suggests that people place higher value on social motives when personal involvement is reduced. Conversely, relative to choosing on behalf of a third-party, when choosing on one's own behalf, the comparison between self-related and social motives may give strategic selfish motives higher value, thereby reducing cooperation levels. These results are in line with research demonstrating strong preferences for social norm behaviour, which are widely shared standards that are based on beliefs about how one should behave in a given situation (Fehr & Fischbacher, 2004a). For instance, bystanders in a social dilemma game were highly motivated to punish players that did not behave in line with the social norm, known as so-called third-party punishment (Fehr &

Fischbacher, 2004b). Furthermore, motives to behave in line with social norms, were also demonstrated by third-party decisions in bargaining contexts (Corradi-Dell'Acqua et al., 2013). They showed that on behalf of a third-party (relative to self) receiving unfair divisions of money, correlated to neural activity in the AI, which has been associated to behaviours such as violating social norms. Conversely, they showed that neural activity in the mPFC correlated to receiving unfair offers on behalf of oneself, which has been found to also correlate to self-related emotions. The aforementioned studies and the current findings of the role of personal involvement on cooperation imply that social preferences for behaviour in line of social norms become more important when deciding on behalf of third-party.

A potential mechanism via which third-party decisions enhance preferences for cooperation is by perspective taking. The process of taking perspective has been linked to enhanced activity in the temporal parietal junction (TPJ) and posterior superior temporal sulcus (pSTS), areas also involved in making inferences about other people's thoughts and feelings, commonly referred to as Theory-of-Mind (Frith & Frith, 2006). These processes have been linked to empathy (Singer et al., 2006), socially salient stimuli (Decety & Lamm, 2007), and other-related preferences in decisions for third-party (Jung et al., 2011; Janowski et al., 2012). The ability to take perspective of others has shown to indirectly increase preferences for social behaviour. Studies on cooperation (Gallagher & Frith, 2003; McCabe et al., 2001; Rilling et al., 2004) reported Theory-of-Mind processes to be involved when choosing to cooperate, suggesting that the ability to take another's perspective plays an important role in cooperation (Stallen & Sanfey, 2013). Thus, third-party decisions may facilitate the individual to take the perspective of the other person. This may result in additional integration of social information when evaluating decision rules and thus lead to different preferences to when comparing and valuating choice options from ones own perspective. Thus, varying the degree of individuals' involvement in the public good shift preferences for cooperation in favour of the collective benefit and away from personal cost-benefit strategies. Future studies could address this more specifically by studying if perspective-taking in the context of cooperation elicits activity in regions referred to Theory-of-Mind network, in particular TPJ, and examine whether this activity subsequently modulates other processes and networks (e.g. mPFC, AI and ACC; Stallen & Sanfey, 2013) correlating with pro-social decisions that match social norm-related behaviour.

A potential alternative interpretation of the results reported here is that instead of increasing individuals' preferences for social outcomes, third-party decisions may reflect a higher willingness to engage in social risk-taking when personal involvement is low. Prior work has reported increased risk-taking with other peoples' money in an investment game (Agranov & Bisin, 2011). However, our results in Study 2 suggest that higher cooperation is not driven by risk preferences, but driven by preferences based on social interests. Here, participants contributed more on behalf of a third-party when playing with humans than when playing with computer players (non-social context). Cooperation for oneself did not show a difference in contribution amounts for human or computer players, which suggest that preferences for self-related outcomes are more valued than social preferences. Nevertheless, in the non-social group context, third-party cooperative decisions were also higher than cooperative decisions for the self, which could potentially suggest a slight increase in risk for third-party. A possible explanation for the differences between self and third-party cooperation in the non-social context is due to an anchoring effect (Tversky and Kahneman, 1974). As shown by the data, we find that people start off with a similar cooperation level independent of the extent of personal involvement. Once they have to cooperate for another beneficiary (either themselves or a third-party), their cooperation preferences shifts relative to their preferences for the previous beneficiary. Cooperation on behalf of a third-party with human players resulted in generally higher cooperation amounts as compared to cooperation for the self. Higher cooperation amounts for third-party may have provided an anchor for cooperation amounts at a higher level when playing with computers. Factors other than social preferences, such as lack of responsibility when ones' own payoffs are not at risk, did not cause higher contributions. Participants decided to cooperate marginally more (relative to the self), when being both jointly involved and choosing on behalf of a third-party with whom they shared the payoff, thereby minimizing lack of responsibility and careless behaviour. That is, participants adjusted their cooperation amounts more in line with behaviour that benefits the group and less towards self-interest. In comparison, participants who were only responsible for the decision for a third-party, but not involved in the payoffs of the public good, showed cooperation levels that were somewhat higher. However, this difference was not significant as compared to choosing for a third-party and sharing the payoff from the public good. Thus, deciding to cooperate on behalf of a third-party enhances cooperation due to increased social preferences for behaviour in line with what is socially widely accepted (Fehr & Fischbacher, 2004a,b).

To conclude, the primary goal of the present study was to examine how choosing for either oneself or another, anonymous, participant could alter preferences for cooperation. In general it has been shown that in these social dilemmas people do not act out of pure self-interest, but also value social interests. We showed that reducing personal involvement in the public goods game, when choosing for a partner or third-party, enhances social interests, as shown by greater cooperation in social contexts as compared to non-social contexts. We speculate that these higher cooperation amounts on behalf of a third-party are a result of taking the other's perspective, leading to increased social preferences. Understanding which processes enhance cooperation is essential to the existence of public goods. The current study provides new insight into third-party decisions of cooperation, and moreover, how choosing on behalf of a third-party encourages people to be more cooperative.

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General Discussion

In this thesis I described how contexts alter the processing of social and non-social risk in situations where the decision-maker is affected by the choice outcome, and in situations when another recipient is affected by the choice outcome. More specifically, I examined how moment-by-moment changes in small monetary reward and punishment contexts affect risk processing and subsequent risky choice, how different positive and negative context types affect subsequent preferences for risk, and how agency affects preferences for social- and non-social monetary risk, in particular, how contexts differently affect decisions on behalf of a third-party as compared to decisions on behalf of oneself.

Overview of the findings in this thesis

In the first empirical chapter (**chapter 2**) I investigated how gain and loss contexts prior to the risky choice affect risk preferences, within-subjects (i.e. framing effects). To investigate this, I examined the neural processes underlying inconsistent risk preferences while evaluating moment-by-moment changes in gain and loss contexts prior to the decision phase. I replicated the behavioural shift in risk preferences, similar to the classic framing effect and in line with previous literature (Kahneman & Tversky, 1979; Tversky & Kahneman, 1981, 1992; De Martino et al., 2006; Tom et al., 2007; Xue et al., 2011). That is, participants who had experienced a gain decided to subsequently choose the safer option (i.e. passing on the gamble), thereby showing a relative aversion to risk. In contrast, when participants were in a loss context, that is when they had just experienced a loss, they showed a shift in preference towards the risky gamble, exhibiting relatively increased risk-seeking tendencies. This was observed for real, consequential, choices. Furthermore, I found the vmPFC responding to a loss context when participants decided to take risk, and also to a gain context when participants subsequently decided to avoid risk. In other words, the vmPFC response reflected the observed preference shift in risk. This demonstrates that the vmPFC may integrate and represent the contextual value of a stimulus in light of subsequent choice. These findings show that a context that is independent of choice outcome, and thereby often ignored when studying decision-making, can have a strong impact on our risk preferences. It highlights the importance of disentangling different phases of the decision-making process to gain a better understanding of unstable risk preferences.

An interesting and open question emerged from this study, namely whether the behavioural effects for mixed monetary gambles observed previously was specific for the type of context, or rather the valence of context. That is, whether there were monetary gains/losses or the fact that an individual was successful or unsuccessful in a task affected risk preferences. **Chapter 3** investigated this question, by separating out the different contexts prior to gambling, and testing whether these shifts in risk were specific for context type. Additionally, the aim was to gain a better understanding as to whether these behavioural effects were primarily driven by one's aversion to losses, or more driven by the valence of the context (positive/negative). I replicated the behavioural findings of chapter 2, that is, risk-taking behaviour was strongly affected by the gain or loss context of the decision, for contexts that involved monetary gains and losses based on task performance. This behavioural effect was strongest for randomly received monetary gains and losses, with an increase in proportion of gambles played after losing money (compared to gaining money). However, performance success and failure feedback, in an unrelated cognitive task, did not differently affect individuals' risk preferences for subsequent mixed monetary gambles. This chapter showed that the observed risky preference shifts are primarily driven by the delivery of monetary gains and losses and not by success or failure in an unrelated task. This highlights the strong context dependence of risk preferences and choices, and demonstrates that valence *per se* does not affect risk preferences, but the type of context is an important moderator in the valuation of risk. Furthermore, these data suggest that loss aversion is enhanced for monetary mixed gambles in contexts that involve monetary gain/loss outcomes. Incompatible contexts, those that are inconsistent to the gamble outcome or goal to be achieved (winning money), do not affect loss aversion for mixed monetary gambles.

Chapters 4 and **5** aimed at exploring how social preferences for risky outcomes in social and non-social settings may change when actively choosing for a third-party. In **chapter 4**, I was particularly interested in examining how prior monetary gain and loss contexts influence risk preferences for identical choice sets when these do not directly affect the agent themselves, but rather are made on behalf of a third-party. Firstly, I replicated the behavioural finding of **chapter 2** and **3** when participants decided for themselves. Secondly, I found that prior gains and losses had less impact on the risk preferences of agents who decided for a third-party. This was shown for identical sets of mixed gambles. Furthermore, when increasing responsibility (personal involvement) of the agent towards the outcome of their actions, gain/loss contexts influenced risk preferences more strongly, as compared to agents with low responsibility. Finally, risk-taking across both gain and loss contexts did not differ between agents deciding for oneself or a third-party. These results indicate that deciding on behalf of third-party specifically alters the context-sensitivity of risk preferences. I speculate that when agents' involvement in the outcomes of the task is reduced, emotional engagement in the task is reduced, therefore gain/loss contexts have a weaker bias on risk preferences.

In the final empirical chapter (**chapter 5**), I continued an investigation on the role of the agent in social decisions concerning uncertain outcomes, in this case cooperative decisions in which the outcome also depends on other players. Firstly, I explored whether being personally involved, jointly involved, or not involved in the outcome of a public good influenced social preferences for cooperation (Study 1). Moreover, assuming agency plays a role, I asked whether third-party decisions are more pro-social or more pro-self? Secondly, I attempted to specify which motives are important when cooperating for a third-party, by examining cooperative decisions with both anonymous other social (human) and non-social (computer) players (Study 2). In Study 1 I found an increased willingness to cooperate when deciding on behalf of a third-party (compared to the self), and most strongly when the individual was not personally involved in the distribution of the public good. These results suggested that third-party cooperation was motivated by social preferences. This is consistent with research demonstrating that individuals are willing to pay a cost to have the other person behave in line with what is deemed pro-social or fair, even when the individual themselves was not affected by the other's selfish behaviour (Fehr & Fischbacher, 2004). In Study 2 I found that cooperation levels on behalf of third-parties were higher when playing with humans (social) as compared to when playing with computers (non-social). On behalf of the self, cooperation levels were lower (compared to third-party), and were the same for social and non-social players. Together, the results of **chapter 5** showed that reducing personal involvement in the public good increased cooperation. Additionally, this increase in cooperation was motivated by social preferences that match social norm-related behaviour. Cooperation on individuals' own behalf was not based on social motives, at least not more than in non-social contexts, but seemed to be mainly motivated by self-related strategic concerns. Finally, the initial cooperation amounts were just below 50%, for both agency conditions, in line with prior literature (Fehr & Gächter, 2000; Fischbacher et al., 2001; Fehr & Camerer, 2007; Camerer, 2003). Differences in cooperation only occurred in the second block, when participants were able to compare the decision to a point of reference (how much they previously contributed). These findings suggest that changing the role of the agent causes people to also shift their preferences relative to a reference point. Shifting agency towards the third-person, by possibly taking the other's perspective, may lead to positively value social preferences, whereas taking the decision from one's own perspective may lead to positively value more selfish concerns.

Context-dependent preferences for risk

The findings in this thesis showed that positive and negative contexts, prior to and unrelated of the gamble, shift reference points in a similar way as choices that are framed as either a gain or a loss (Tversky & Kahneman, 1981). Furthermore, the observed difference in risk-taking for mixed gambles following gain and loss contexts can be explained by the concept of loss aversion, in line with Prospect Theory (Kahneman & Tversky, 1979). That is, losses loom larger than equivalent gains, and because of this sensitivity to losses, people are highly motivated to avoid loss outcomes. Thus, when in a loss situation, the willingness to avoid this loss becomes so high that we are willing to override our risk aversion and take a gamble, whereas when in a gain situation, our existing loss aversion is enhanced.

Interestingly, the vmPFC evaluated risk preferences for identical risky gambles differently, depending on the prior context. Importantly, this finding provides additional evidence that the context has a large effect on ones' risk preferences, not only behaviourally, but also in affecting the underlying brain processes that are involved in comparing and computing choice values and signalling the final choice option. Additionally, the results of this thesis extend our knowledge of the diverse but crucial role of the vmPFC in risky decision-making, such as signalling expected value (Platt & Huettel, 2008; Rangel et al., 2008; Rangel & Hare, 2010; Tom et al., 2007), the final chosen option (Boorman et al., 2009), predicting choice (Lebreton et al., 2009; Levy et al., 2011), and integrating contextual appraisals (Rosenbloom et al., 2012; Sokol-Hessner et al., 2012b). These results suggest that the vmPFC is a critical area in the ability to integrate multiple attributes in the assessment of risky choice preferences.

Brain mechanisms for context effects have been studied before. These studies however explored how the brain evaluates a gamble option when these are presented as either a gain or loss, with these framing effects correlating with an underlying emotional response (De Martino et al., 2006). In this thesis, I specifically explored how independent small gain/loss contexts, separately and prior to the same gambles, might influence how we value the context in light of playing the gamble or not. This shows that by changing the context at different phases, a similar behavioural response can have different effects on the underlying process of risky choice.

The contextual framing effect observed here is only apparent when it is compatible (i.e. monetary context) and possibly more relevant to the subsequent choice and goals (i.e. to earn money). These results postulate that the vmPFC might only be integrating those attributes that contain goal-relevant information. This is in line with observations in lesion studies, showing that the vmPFC is important in informing patients when risk should be inhibited (Sanfey et al., 2003; Shiv et al., 2005), and also in representing relevant preferences for the current choice option (Nicolle et al., 2012), and in goal-directed choice (Basten et al., 2010).

To summarize, seemingly relevant context outcomes seem to have a great effect on behaviour and it is important to take this into consideration when studying risk preferences. Moreover, the compatibility of the context relative to the choice itself would seem to be an important moderator in the valuation of risk preferences for the subsequent choice. This highlights the strong and specific context dependency of risk preferences and choice. Critical areas involved in anticipating reward/punishment and involved in emotional response to uncertain outcomes, guide choice behaviour consistent with minimizing losses and maximizing gains (i.e. Prospect Theory; Kahneman & Tversky, 1979).

Agency and monetary risk

Living in a social environment involves interaction with other people and entails that the many choices we face are not always made on behalf of ourselves. Often a friend or even a stranger may ask you what you would do in their position, sometimes even asking you to actively decide for them. Integrating potential modulatory effects that others may have on our risk preferences and choices enriches current knowledge of decision-making. Several studies have attempted to examine whether deciding for others increases or decreases our tendencies to take risk, such as when investing other peoples' money (Eriksen & Kvaløy, 2011), or when gambling with the total pot of money on behalf of ourselves and the entire group (Reynolds & Jackson, 2009). Different methodologies may have led to differences in results.

This thesis demonstrated that choosing on behalf of third-party decreases the sensitivity to prior gain and loss outcomes (i.e. reduced effect of context), which potentially underlies a reduced engagement of affective processes, that are known to bias decisions for gains and losses (Sokol-Hessner et al., 2009; De Martino et al., 2006, 2010; Canessa et al., 2013). Other studies examining third-party decision-making have also found evidence for a reduced emotional input while deciding for others, resulting in diminished loss aversion (Mengarelli et al., 2014; Polman, 2012), and concerning social preferences for fairness (Civai et al., 2010). Along these lines, responsibility or personal involvement is closely linked to self-referential emotions during decision-making (Berndsen, et al., 2004; Chang et al., 2011; Camille et al., 2004, 2010; Coricelli et al., 2007). These studies further support the idea that decisions made for a third-party, with decreased personal involvement, are less affect-biased, and therefore show attenuated sensitivity to the context, whereas increasing personal involvement or responsibility increases the affective impact of gain/loss outcomes, resulting in a stronger shift in risk preferences.

The current research gives some insight into the debate about the role of agency or third-party effects on risk. Only when integrating different gain and loss contexts in studying risk preferences do we find that participants' willingness to play identical gambles for a third-party was different as compared to playing for oneself. However, *overall*, across contexts, levels of risk-taking did not differ (**chapter 4**; Stone et al., 2002).

Agency in socially risky environments

The role of personal involvement in cooperative decisions has been understudied. There are many situations in which decisions affecting others are delegated, and when the decision-maker themselves are not affected (e.g. CEO deciding benefits for his employees). It is important to understand how these decisions are made, and whether these decisions are made with an interest for the collective in the long run (considering the risk involved) or rather influenced by self-related concerns.

One factor that seems to increase cooperation, and thereby potentially places more weight on social concerns, is the ability to take the perspective of others (McCabe et al., 2001). In a similar vein to **chapter 4**, taking the other's perspective when considering contributing to a public good might reduce the value of individual outcomes, and increase value on outcomes that are beneficial in the long run (**chapter 5**). This is also in line with studies showing that third-party choices are less impulsive when deciding between sooner smaller rewards versus later larger ones (Albrecht et al., 2011; Ziegler & Tunney, 2012; Kim et al., 2013).

In **chapter 5** pro-social behaviour for cooperative decisions increased particularly when first having made the cooperative decisions for oneself. In the case of people first deciding on behalf of others whether they should cooperate, and then next for themselves, cooperation is reduced. This highlights the importance of the context of the decision and shows that people weigh the decision to cooperate relative to a reference point, which is often observed to be somewhat less than half of the amount they can contribute. In other words, and similarly to gain and loss contexts in **chapter 4**, defecting or cooperating is observed relative to the reference point, which depends on the current context (i.e. first- or third-person). Due to the uncertainty of the behaviour of others, cooperation is a risky decision, with free-riding being an act that ensures the safest and highest outcome. If others do not cooperate and the individual does, then he will be worse off, and make a "loss". However, previous literature, as well as this thesis, showed that people are willing to take the risk and act partially pro-social by sharing some of the personal benefit (Camerer, 2003). Moreover, researchers are currently studying the use of incentives in increasing cooperation and reducing free-riding (Fehr & Fischbacher, 2004). Using incentives when choosing on behalf of a third-party may actually be less helpful, as third-party choices are less affected by reward and punishment outcomes (**chapter 4**).

Together, third-party decisions affect risk preferences for monetary and social outcomes, for gain and loss contexts as well as for social and non-social contexts. Third-party decisions are not more risky than choices for oneself, for financial decisions as well as cooperative decisions. Agency shifts reference points, to which monetary gains and losses, and material self-interest and social interest are compared. The behavioural findings in this thesis indicate that affective processes that usually accompany gain and loss outcomes are less involved in third-party decisions.

Challenges and future implications

In this thesis some questions remained unanswered that, I believe, are interesting and meaningful for future studies.

To understand whether compatibility or goal relevance is a critical factor to influence risk preferences for monetary outcomes (**chapters 2** and **3**), future studies could examine whether the underlying mechanisms for incompatible contexts are altered. For instance, if only relevant contexts are integrated into the computation of stimulus value and choice, we would expect the vmPFC to be specifically sensitive to relevant and not to irrelevant contexts. To test this, the relevance of contexts needs to be clear and goals need to be testable to know whether specific contextual signals are necessary for goal achievement. In **chapter 2** I did not have data to test how the integration of decision context (i.e. gain and loss) by the vmPFC may vary for the different expected values of gambles. This is an interesting open question for understanding a potential adaptive role of the vmPFC in combining different values in guiding risk behaviour.

It is important to integrate the context in studying decisions to better understand in which contexts peoples' preferences are most susceptible. This knowledge may help to better regulate processes triggered by these contexts, in case unrelated contexts may result in unwanted behaviour; for example, brokers in the financial market may not always want to be influenced by prior losses or gains. Additionally, it would also be interesting to study whether cross-domain contextual effects exist for non-monetary choices involving risk, e.g. health-related decisions, which could provide knowledge and implications about context effects for general uncertain choices. Currently, this thesis provides some insight into cross-domain contextual influences on risk preferences. Successful and unsuccessful performance feedback did not influence risk behaviour for monetary gambles, in line with earlier findings on compatibility effects (Slovic et al., 2002). Conversely, in different settings, unrelated, contextual influences do sometimes exist (Knutson et al., 2008; Stanton & Reeck, 2014). Examining underlying differences mediated by different context domains could provide more insight into how these different sources may affect our valuation of risky choice.

Future studies could examine how brain mechanisms compute values of outcomes and contexts when these are not personal, and how this shapes preferences for others. It is assumed that perspective-taking modulates the decision process for others. However, more research is necessary to understand how this would influence underlying processes of risk and non-risk choices in social and non-social risk settings. This could provide a better idea of whether cooperative decisions are experienced as being less risky or whether social preferences are valued higher. Perspective taking could reduce the disutility of non-reciprocation by others. It is known that societies with cooperative individuals work better than societies with selfish people. If solely changing perspectives enhances individuals to become more cooperative, this could have implications in understanding how to encourage social behaviour such as cooperation.

A limitation in studying social decision-making is the games used to study cooperation. These tasks provide simple paradigms to examine social interactive choice. However, they often capture strategic behaviour more than social behaviour. Furthermore, the redistribution of the outcome in public good games do not resemble real public goods, where the outcome is often of a different commodity to that was put in, and of which the consumption often occurs at a later point in time. Simple paradigms that reflect real-life cooperation are required to gain a better understanding of the process underlying cooperation, e.g. paradigms in which cooperation requires real effort, or outcomes with varying time delays. Research on temporal discounting may give us information into how these decisions are made. Moreover, observations from third-party decisions for intertemporal choices imply that third-party cooperation may increase the ability to focus on long term benefits of cooperation, thereby optimizing social choice behaviour. Future work should attempt to investigate the temporal aspects of cooperative decisions and examine which mechanisms may also be important during third-party choices in social and non-social risk settings. Improving knowledge of these contextual influences and third-party choices may provide interesting opportunities for policy implications. For instance, adjusting the temporal aspect of the outcome or inducing people to take a different perspective might result in more cooperation.

In real-life situations we experience a constant stream of feedback from our own actions and from social interactions, but also from events that are beyond our control. For a more comprehensive understanding of risky decision-making, it is therefore important to include contexts as part of the experimental design, but to distinguish it from choice. As shown here, not separating the in-built task contexts from the choice itself can confound measures of risk preferences. Feedback from social interactions is often not given at all, because of confounding the measurement of "pure" social preferences. Using designs in which repeated interactions do not confound the measurement of social preferences is difficult, but can better inform and predict social preferences in risky dynamic interactive contexts.

Studying decision-making from a neuroeconomics perspective is both exciting and challenging at the same time. Firstly, integrating the different disciplines (economics, psychology and neuroscience) entails many different concepts that may not all mean the same in each discipline. Each discipline has its own preference for particular methodologies in answering questions of interest. Despite these challenges, the interdisciplinary approach in neuroeconomics provides a more comprehensive view and understanding of how and why individuals make specific decisions, and incorporates this knowledge to create more accurate models capturing decision-making behaviour in real-life settings.

Conclusion

In this thesis, I have investigated individual and social preferences for social and non-social risk, by combining tasks and research from experimental economics, social psychology and neuroscience. I have argued the importance of context in the decision-making process. Integrating the respective decision context is essential in order to gain a comprehensive view of how preferences for risk are formed and influenced. Furthermore, this thesis has provided some additional insight into the relatively understudied field of third-party risk-taking. The main aim here is to improve the understanding of the neural and psychological processes that underlie decision-making under risk in social and non-social settings.

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APPENDIX

Nederlandse samenvatting | *Dutch summary*

Ons leven bestaat uit het nemen van tal van beslissingen, van dagelijkse keuzes omtrent hoeveel geld we willen sparen, tot aan complexere keuzes, zoals het kopen van een huis. Daarnaast bieden de meeste keuzes niet altijd een zekere uitkomst, maar bevatten een zeker risico. Volgens traditionele theorieën over besluitvorming zou men altijd de beste optie moeten kiezen en deze beslissing consistent na moeten volgen, zonder daarbij beïnvloed te worden door andere factoren. Onderzoek toonde aan dat mensen dit in de werkelijkheid niet doen. Wanneer mensen bijvoorbeeld een keuze hebben tussen het accepteren van een zekere 20 euro winst, of accepteren van een 50% kans op 40 euro winst en 50% kans op helemaal niks, kiest het merendeel voor de zekere 20 euro. Men is over het algemeen dus risicomijdend. Daarentegen, wanneer mensen de keuze hebben tussen een zekere 20 euro verlies accepteren of 50% kans op 40 euro verlies met 50% kans op geen verlies, dan kiest het merendeel om een gok te wagen. Oftewel, we zijn nu risico-zoekend. Ondanks dat deze keuze in principe hetzelfde is, waarbij enkel de ene keer een winst kan worden gemaakt en de andere keer een verlies kan worden geleden vertoont men een andere voorkeur. De inconsistente voorkeur voor een riskante optie kan worden verklaard door onze aversie voor verliezen ('loss aversion'). De aversie voor verliezen zorgt ervoor dat we een verlies erger vinden dan een gelijksoortige winst (wel ongeveer 2 maal zo erg), en hierdoor gemotiveerd zijn om een verlies te vermijden. In het geval dat een gok een kans op een verlies kan wegstrepen, kiest men hiervoor, ondanks dat eenzelfde grote kans bestaat dat ze een twee maal groter verlies kunnen maken. Onze keuzes worden dus beïnvloed door indirecte factoren, zoals de situatie of *context* waarin we op dat moment een keuze maken. Naast dat we continue keuzes maken voor onszelf, maken we onze keuzes ook binnen een sociale context, in dit geval beïnvloeden onze keuzes niet alleen onszelf maar ook anderen. Er wordt veel onderzoek gedaan naar hoe men risicovolle beslissingen neemt vanuit psychologie, economie en neurowetenschappen. Dat heeft geleid tot een interdisciplinair onderzoeksgebied genaamd Neuro-economie, die de kennis, modellen en technieken vanuit deze drie disciplines combineert om besluitvorming in mensen en dieren beter in kaart te brengen.

In dit proefschrift heb ik vanuit een neuro-economische benadering onderzocht hoe verschillende sociale- als niet-sociale contexten onze risicovolle beslissingen beïnvloeden. In **hoofdstukken 2** en **3** heb ik onderzocht hoe veranderingen in de context, zoals het ervaren van financiële beloningen en straffen, het beslissingsproces en de uiteindelijke keuze beïnvloeden. Daarbij heb ik gekeken hoe de hersenen deze context verwerken terwijl we deze keuzes maken. **Hoofdstuk 2** laat zien dat deelnemers de zekere optie vaker kozen dan de riskante optie nadat ze zojuist geld hadden gewonnen en dus risicomijdend werden, terwijl ze juist de gok waagden wanneer ze zojuist geld hadden verloren, en dus risico-zoekend werden. Oftewel, de keuze om risico te nemen werd beïnvloed door de winst en verlies context waarin ze de keuze maakten, waarbij we na verliezen bereid waren een risico te nemen op een eventueel groter verlies. Dit zagen we voor beslissingen waarbij telkens dezelfde financiële keuze werd voorgelegd, en echt geld te verdienen was. Daarnaast laat ik zien dat dit keuzegedrag samenhangt met hersenactiviteit in de ventromediale prefrontale cortex, een hersengebied dat betrokken is bij het berekenen van de waarde van keuze opties en het signaleren van de uiteindelijke keuze. Dit hersengebied bleek dus sensitief te zijn voor de contextuele informatie.

De resultaten van **hoofdstuk 2** leverde een interessante vervolgvraag op, namelijk, of de gedragseffecten specifiek zijn voor de type context of voor de positieve of negatieve lading van de context. Met andere woorden, zijn de gedragseffecten specifiek voor het feit dat ze net geld hebben gewonnen of verloren, of het feit dat de deelnemers goed of slecht presteerden in de voorafgaande taak. In **hoofdstuk 3** heb ik dit onderzocht. De resultaten bevestigde de eerder gevonden verschillen in risicovolle besluitvorming. Dit gedrag werd enkel geobserveerd bij een context waar geld werd gewonnen of verloren, en niet zo zeer door positieve en negatieve feedback bij succes of falen van een taak. Deze resultaten suggereren onder meer dat onze beslissingen voor riskante financiële opties voornamelijk gedreven worden door een context waarbij geld winnen of verliezen een rol speelt, en dat deze context onze aversie voor verlies versterkt. Beiden hoofdstukken laten zien dat de context waarin een keuze zich afspeelt een belangrijke factor is op ons gedrag, hoewel deze objectief gezien niet relevant is voor de risicovolle keuze.

In **hoofdstukken 4** en **5** van dit proefschrift heb ik de sociale invloed op ons keuzegedrag onderzocht. In een sociale samenleving beïnvloeden onze keuzes niet alleen onszelf maar ook anderen. Daarnaast maken we ook keuzes namens of voor een ander, zoals ouders voor hun kinderen. Ondanks de directe impact dat dit soort keuzes op ons hebben, is er nog geen eenduidig resultaat gevonden of we anders kiezen voor een ander dan voor onszelf. In de context van risicovolle beslissingen is dit interessant, aangezien eerder onderzoek en de vorige hoofdstukken in dit proefschrift laten zien dat deze beslissingen gemakkelijk worden beïnvloed door de context. In **hoofdstuk 4** heb ik onderzocht hoe voorafgaande positieve en negatieve contexten onze keuze voorkeur voor risico beïnvloeden wanneer we deze keuze maken voor andere personen. Ten tweede onderzocht ik of het uitmaakt in hoeverre iemand verantwoordelijk is in de besluitvorming en uitkomst daarvan. De gedragsbevinding van **hoofdstuk 2** en **3** waarbij de deelnemers voor zichzelf kozen, werden hier gerepliceerd. Opvallend is dat voorafgaande winsten en verliezen minder invloed op de risico voorkeuren en keuzes van de beslissers hadden wanneer diegene namens een ander koos. Bovendien, bij het verminderen van de verantwoordelijkheid (persoonlijke betrokkenheid) van de beslissers voor de uitkomst van hun acties, beïnvloedden de winst of verlies contexten de risicovolle keuzes minder, in vergelijking met beslissers met meer verantwoordelijkheid en diegene die voor henzelf kozen. Tenslotte namen de beslissers gemiddeld niet meer of minder risico voor een ander ten opzichte van beslissers die voor henzelf kozen. Deze resultaten geven aan dat wanneer we een beslissing nemen namens anderen, de context-gevoeligheid van onze voorkeur om risico te nemen specifiek verandert. Ik speculeer hier dat wanneer betrokkenheid van de beslissers in de uitkomsten van de taak vermindert, hun emotionele betrokkenheid voor de context in de taak reduceert, en vervolgens resulteert in een zwakker effect van de winst of verlies context op hun voorkeur om risico te accepteren.

In het laatste empirische hoofdstuk (**hoofdstuk 5**), vervolgde ik mijn onderzoek naar de rol van de beslisser in sociale keuzes met onzekere uitkomsten, in dit geval beslissingen om samen te werken ofwel te coöpereren, waarbij de uitkomst ook afhankelijk is van andere spelers. Een voorbeeld zijn grootschalige beslissingen omtrent samenwerking, die vaak worden gemaakt door individuen namens andere mensen (bijv. de overheid). In dit hoofdstuk heb ik onderzocht hoe persoonlijke betrokkenheid bij een publiek goed (bijv. schone lucht) samenwerking kan beïnvloeden. Ik vroeg mij af of sociale beslissingen namens anderen pro-socialer zijn of juist niet, en welke motieven ten grondslag liggen aan sociale besluitvorming namens anderen. **Hoofdstuk 5** laat zien dat deelnemers het meeste samenwerken voor een publiek goed wanneer zij de beslissing namen voor een andere deelnemer, en niet persoonlijk betrokken waren bij de uitkomst en verdeling van het publiek goed, terwijl deelnemers het minste samenwerken wanneer persoonlijke betrokkenheid hoog was (d.w.z. namens henzelf kozen). De resultaten komen overeen met eerder onderzoek waaruit blijkt dat mensen bereid zijn om een prijs te betalen om andere personen zich meer in lijn van sociale normen te laten gedragen, zoals wat sociaal en eerlijk geacht wordt, zelfs wanneer het individu zelf niet getroffen werd door het zelfzuchtige gedrag van de ander. Ten tweede laat ik zien dat de keuze om meer bij te dragen aan het publieke goed namens een ander gedreven werd vanuit sociale motieven. De bijdrage in samenwerking leek aanvankelijk afhankelijk te zijn van de betrokkenheid van de beslisser. Verschillen in samenwerking traden alleen op wanneer de deelnemers hun huidige situatie konden vergelijken ten opzichte van een eerdere situatie waarin ze dezelfde keuze kregen. Wanneer we de beslissing over de mate van samenwerking namens onszelf veranderde naar dat namens een ander, lijken we meer te denken aan het sociale belang, wat resulteert in meer samenwerking. Anderzijds wanneer we de beslissing namens de ander nu vanuit eigen perspectief nemen dan lijken we meer gemotiveerd te worden door ons eigen belang, wat minder samenwerking of zelfs 'free-riding' (ofwel 'zwartrijden': gebruik maken van het publieke goed zonder daar zelf in te investeren) tot gevolg kan hebben. Tezamen laten de resultaten van **hoofdstuk 5** zien dat het verminderen van persoonlijke betrokkenheid in het publieke goed tot meer samenwerking leidt, en gedreven wordt door sociale preferenties, die in overeenstemming zijn met sociale normen.

Relevantie & Conclusie

Het doel van dit onderzoek is om meer kennis te krijgen over hoe mensen tot bepaalde keuzes komen en door welke factoren keuzes worden beïnvloed, om vervolgens beter te voorspellen en te begrijpen hoe en welke beslissingen mensen nemen.

In realiteit ervaren we een constante stroom van feedback van ons eigen handelen en van de sociale invloeden om ons heen, maar ook van gebeurtenissen die buiten onze controle plaatsvinden. Om beter te begrijpen hoe risicovolle keuzes gemaakt worden, is het daarom belangrijk om de context als onderdeel van de experimentele opzet te omvatten. De bevindingen in dit proefschrift dragen bij aan deze kennis, en laat zien dat onze beslissingen makkelijk beïnvloed worden door een voorgaande situatie. Zelfs wanneer de keuze hetzelfde is en de context objectief irrelevant is, kan het toekomstige beslissingen aanzienlijk beïnvloeden. Tevens geeft dit proefschrift inzicht in de sensitiviteit van onze keuzes voor verschillende contexten en wijzen erop hoe flexibel onze risico voorkeuren en keuzes zijn. Het onderzoek in dit proefschrift geeft meer inzicht in de neuronale mechanismen in context-afhankelijke en risicovolle besluitvorming. Daarnaast benadrukt dit proefschrift het belang van de sociale context van de beslissing en de rol van de beslisser in de keuze. Tevens wordt het belang van het bestuderen van de context van de keuze extra aangetoond in de discussie over de rol van de beslisser in risicovolle keuzes. Tot slot, laat ik zien dat subtiele veranderingen in de context, zoals wanneer mensen niet voor henzelf maar namens een ander kiezen om wel of niet samen te werken, effectief kunnen zijn om samenwerking te verhogen en eventueel verminderen van 'free-riding'. Het vergroten van de kennis over de mogelijke invloeden van sociale en niet-sociale contextuele informatie op onze besluitvorming, besproken in dit proefschrift, kan interessante bijdragen hebben voor beleidsvorming.

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List of publications

Losecaat Vermeer, A. B., Boksem, M. A. S., & Sanfey, A. G. (2014). Neural mechanisms underlying context-dependent shifts in risk preferences. *NeuroImage*, *103*, 355–363.

Losecaat Vermeer, A. B. & Sanfey, A. G. (*under revision*). The effect of positive and negative feedback on risk-taking across different contexts.

Losecaat Vermeer, A. B., Boksem, M. A. S. & Sanfey, A. G. (*under review*). Third-party decision-making under risk as a function of prior gains and losses.

Losecaat Vermeer, A. B., Heerema, R. L. & Sanfey, A. G. (*under review*). Third-party Cooperation: How reducing personal involvement enhances contributions to the public good.

Losecaat Vermeer, **A. B.**, Sanfey, A. G., Foroni, F., & Rumiati, R. I. (*in prep*). Different engagement of hot and cold processing in third-party risk-taking.

Curriculum Vitae

Annabel Losecaat Vermeer was born on May 8, 1985, in Nieuwegein, The Netherlands. She grew up in the countryside in Drenthe, where she graduated from high school in 2004. She retuned to Utrecht to study Biology at Utrecht University. Initially she wanted to become a veterinarian, but after a year into her Bachelor she became more interested in human behaviour. She continued with a Master in Neuroscience and Cognition at Utrecht University in 2008. As part of her Master she did a research internship at the Military Mental Health Care research centre in Utrecht, part of the Ministry of Defence. Under supervision of Dr. Elbert Geuze and Dr. Saskia van Liempt, she studied the effects of fragmented sleep periods on memory consolidation in Dutch war veterans with PTSD, using fMRI and EEG. She also did a second research project as part of her Master at the University of Cambridge, United Kingdom. Here she worked with Dr. Luke Clark on the effects of stress on biases in risky decision-making. In 2011 Annabel started her PhD project on the cognitive neuroscience of decision-making, under supervision of Prof. Alan Sanfey and Prof. Ap Dijksterhuis. She did her PhD studies at the Behavioural Science Institute of the Radboud University Nijmegen, and the Donders Institute for Brain, Cognition and Behaviour in Nijmegen. During her PhD, Annabel did a 2-month research visit, as part of a research grant she won, to work with Prof. Raffaella Rumiati and Dr. Francesco Foroni at the International School for Advanced Studies (SISSA) in Trieste, Italy. As of May 2015, Annabel is working as a Post-doctoral researcher in the lab of Dr. Christoph Eisenegger at the University of Vienna, in Austria. Here she continues her work in studying human decision-making.